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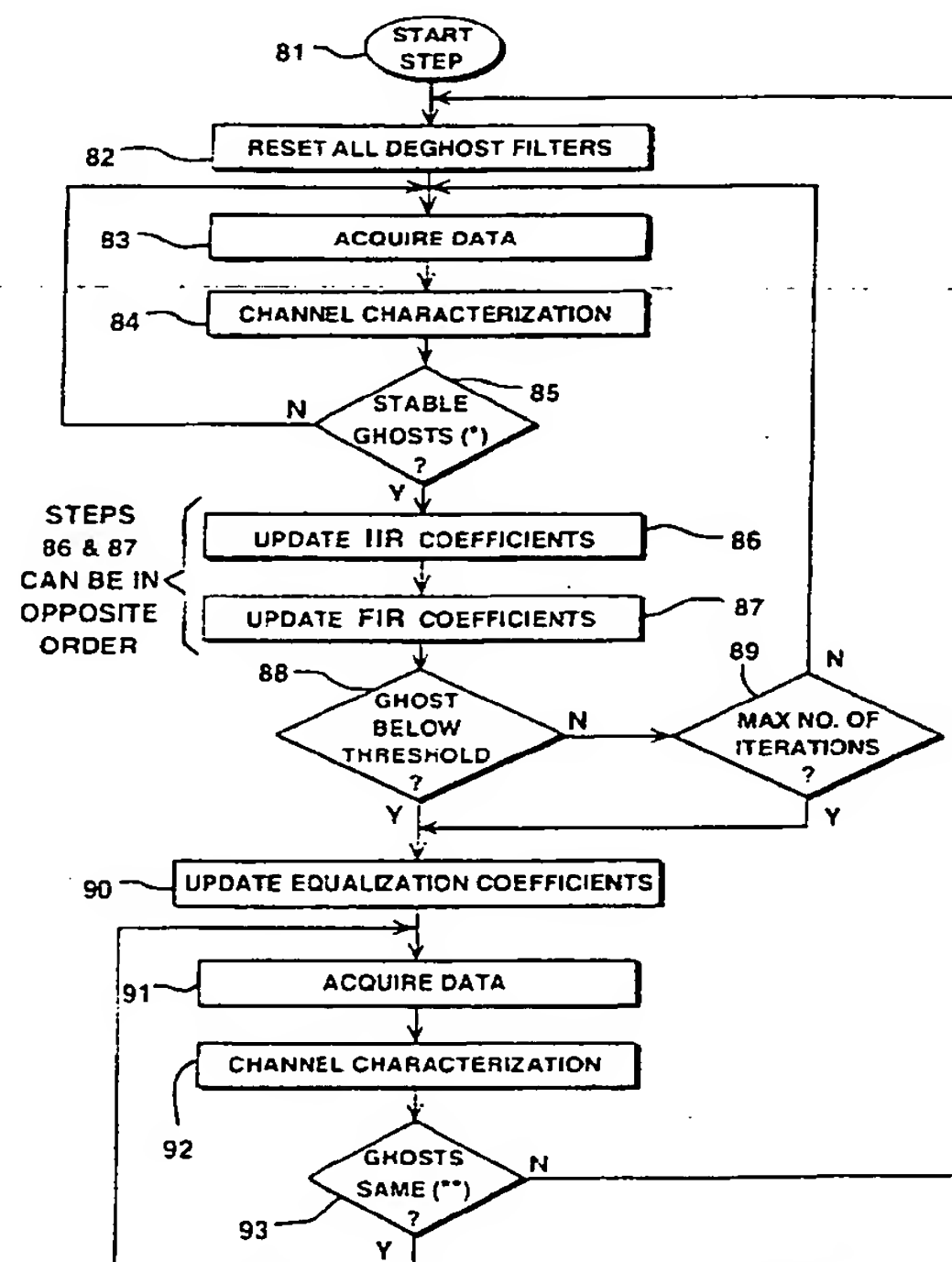(84) Designated Contracting States :
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(54) **Video ghost cancellation.**

(57)   Ghosts accompanying a composite video signal are suppressed using one filter to suppress macroghosts and another filter to suppress microghosts, the filtering parameters of each of these filters being adjustable in response to digital programming signals generated by a computer. Computational methods are described, each of which includes data acquisition and channel characterization steps followed by a decision step comparing the most recent set of channel characterization results with the next most recent set to determine whether stable ghosting conditions obtain. The data acquisition and channel characterization steps are looped back through until stable ghosting conditions obtain, so the subsequent calculations of the filtering parameters for the filter used for suppressing macroghosts are accurately performed. Where the filter to suppress macroghosts comprises IIR and FIR sections for suppressing post-ghosts and preghosts, respectively, these calculations are carried out to a great extent on a separable basis, simplifying the calculations appreciably. Then, each of these methods performs a step of calculating the filtering parameters for the FIR filter used for suppressing microghosts. This step is followed by further data acquisition and channel characterization steps, followed by a decision step comparing the most recent set of further channel characterization results with the next most recent set of further channel characterization results to determine whether they are substantially the same. If the sets of further channel characterization results are substantially the same, either method loops back to the further data acquisition step ; if the sets differ appreciably, either method resets the adjustable filtering parameters for the filters to initial values and the method restarts automatically.

Fig. 4

(*) DIFFERENCE BETWEEN TWO CONSECUTIVE CHANNEL ESTIMATIONS IS BELOW THRESHOLD

(**) RESIDUE GHOSTS IN BOTH STEP 84 AND STEP 92 CHANNEL CHARACTERIZATIONS ARE ALL BELOW THRESHOLD

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The invention relates to ghost-cancellation circuitry as used, for xample, in a television receiver or in a video tape r corder and, m re particularly, but not exclusively, to methods for calculating the parameters of filters used for suppressing ghosts in composite video signals supplied from the video detector of a TV receiver or video tape recorder.

Television engineers have given considerable thought to ghost-cancellation circuitry for inclusion in television receivers that also include a display device for reproducing the television image in a form suitable for viewing by humans. Ghost images, caused by multipath reception and commonly referred to as "ghosts", are a common occurrence in television pictures that have been broadcast over the air or have been transmitted by cable.

The signal to which the television receiver synchronizes is the strongest of the signals it receives, which is called the reference signal, and is usually the direct signal received over the shortest reception path. The multipath signals received over other paths are thus usually delayed with respect to the reference signal and appear as trailing ghost images. It is possible, however, that the direct or shortest path signal is not the signal to which the receiver synchronizes. When the receiver synchronizes to a reflected (longer path) signal, there will be a leading ghost image caused by the direct signal, or there will be a plurality of leading ghosts caused by the direct signal and other reflected signals of lesser delay than the reflected signal to which the receiver synchronizes. The parameters of the multipath signals -- namely, the number of different-path responses, the relative amplitudes of the different-path responses, and the differential delay times between different ones of the different-path responses -- vary from location to location and from channel to channel at a given location. These parameters may also be time-varying. The visual effects of multipath distortion can be broadly classified in two categories: multiple images and distortion of the frequency response characteristic of the channel. Both effects occur due to the time and amplitude variations among the multipath signals arriving at the reception site. When the relative delays of the multipath signals with respect to the reference signal are sufficiently large, the visual effect is observed as multiple copies of the same image on the television display displaced horizontally from each other. These copies are sometimes referred to as "macroghosts" to distinguish them from "microghosts", which will be presently described. In the usual case in which the direct signal predominat s and the receiver is synchronized to the direct signal, the ghost images ar displaced to the right at varying position, intensity and polarity. These are known as trailing ghosts or "post-ghost" imag s. In the l ss frequently encountered case where the receiver synchronizes to a reflected signal, there will be one or more ghost images displaced to the left of the reference image. These ar known as leading ghosts or "preghost" images.

Multipath signals of relatively short delays with respect to the reference signal do not cause separately discernible copies of the predominant image, but do introduce distortion into the frequency response characteristic of the channel. The visual effect in this case is observed as increased or decreased sharpness of the image and in some cases loss of some image information. These short-delay, close-in or nearby ghosts are commonly caused by unterminated r incorrectly terminated radio-frequency transmission lines such as antenna lead-ins or cable television drop cables. In a cable television environment, it is possible to have multiple close-in ghosts caused by the reflections introduced by having several improperly terminated drop cables of varying lengths. Such multiple close-in ghosts are frequently referred to as "micro- ghosts".

Long multipath effects, or macroghosts, are typically reduced by cancellation schemes. Short multipath effects, or microghosts, are typically alleviated by waveform equalization, generally by peaking and/or group-delay compensation of the video frequency response.

Since the characteristics of a transmitted television signal are known a priori, it is possible, at least in theory, to utilize such characteristics in a system of ghost signal detection and cancellation. Nevertheless, various problems limit this approach. Instead, it has been found desirable to transmit repeatedly a reference signal situated, for example, in a section of the TV signal that is currently unused for video purposes and to utilize this reference signal for the detection of ghost signals prior to arranging for the suppression of ghost signals. Typically, lines in the vertical blanking interval (VBI) are utilized. Such a signal is herein referred to as a Ghost Cancelling Reference (GCR) signal; and a variety of different GCR signals have been described in patents and other technical publications.

Bessel pulse chirp signals are used in the GCR signal recommended for adoption as a standard for television broadcasting in the United States of America. The distribution of energy in the Bessel pulse chirp signal has a flat frequency spectrum extending continuously across the video frequency band. The chirp starts at the lowest frequency and sweeps upward in frequency therefrom to the 4.1 MHz highest frequency. The chirps are inserted into the first halves of selected VBI lines, the 19th line of each field currently being preferred. The chirps, which are on +30 IRE pedestals, swing from -10 to +70 IRE and begin at a prescrib d time after the trailing edges of the preceding horizontal synchronizing pulses. The chirp signals appear in an eight-field cycl in which the first, third, fifth and seventh fields have a polarity of color burst defined as being positiv and the second,

fourth, sixth and eighth fields have an opposite polarity of color burst defined as being negative. The initial 'lobe of a chirp signal ETP that appears in th first, third, sixth and eighth fields of an eight-field cycle swings upward from the +30 IRE pedestal to +70 IRE level. The initial lobe of a chirp signal ETR that appears in the second, fourth, fifth and seventh fields of the eight- field cycle swings downward from the +30 IRE pedestal to -10 IRE level and is the complement of the ETP chirp signal.

The strategy for eliminating ghosts in a television receiver relies on the transmitted GCR signal suffering the same multipath distortions as the rest of the television signal. Circuitry in the receiver can then examine the distorted GCR signal received and, with a priori knowledge of the distortion-free GCR signal, can carry out a procedure known as channel characterization, in which the magnitudes, phases and occurrence times of the ghosts are determined respective to the reference signal. This is done by calculating the discrete Fourier transform (DFT) of the ghosted GCR signal and dividing the terms of that DFT by the corresponding terms of the DFT of the non-ghosted GCR signal known a priori, thus to generate the respective terms of the DFT of the channel. These DFTs are all in the time domain. The occurrence times of the ghosts and the amplitudes of their inphase components are then used for calculating the adjustable weighting coefficients of a digital filter through which the composite video signal from the video detector is passed to supply a response in which ghosts are suppressed, which filter is referred to as a "ghost-cancellation" filter in this specification. The terms of the channel DFT are analyzed to determine the largest of them, which is replaced by zero in a modified DFT. The other terms are reversed in sign in the modified DFT, which is the desired DFT of the ghost-cancellation filter. The weighting coefficients of this ghost-cancellation filter are adjusted to approximate this desired DFT as closely as possible. The GCR signals can be further used for calculating the adjustable weighting coefficients of an equalization filter connected in cascade with the ghost-cancellation filter, for providing an essentially flat frequency spectrum response over the complete reception path through the transmitter vestigial-sideband amplitude-modulator, the transmission medium, the television receiver front-end and the cascaded ghost-cancellation and equalization filters.

The present inventors have configured a ghost-cancellation filter as a cascade connection of a recursive digital filter principally us d for canc lling post-ghosts and a non-recursive digital filter principally used for cancelling pr ghosts. A r cursiv digital filter has an infinite impuls response, so is commonly referred to as an IIR filter. A non-recursive digital filter has finite impulse response, so is commonly referred to as an FIR filter. On may seek to carry out adjust-

ments to the IIR and FIR filters independently, directly relating th small r terms of the DFT of said reception channel later in time than the largest term of the DFT of said reception channel to tap weights in the IIR filter, and directly relating the smaller terms of the DFT of said reception channel earlier in time than the largest term of the DFT of said reception channel to tap weights in the FIR filter. Directly relating the DFT terms to tap weights in the filters is a relatively simple computational procedure that was followed in the prior art when just post-ghosts or just preghosts were being corrected.

Suppose, then, that those portions of the channel characterization results descriptive of post-ghosts are used to adjust the filtering coefficients of just the IIR filter principally used for cancelling p st-ghosts. Suppose further those portions of the channel characterization results descriptive of preghosts are used to adjust the filtering coefficients of just the FIR filter principally used for cancelling preghosts. When the IIR filter adjustments and FIR filter adjustments are carried out independently, ghost suppression is good when there are only post-ghosts and not too many of them. Ghost suppression is also good when there are only preghosts and not too many of them.

Ghost suppression tends to be poor, however, when there are both post-ghosts and preghosts of appreciable energy, even though the ghosts are f w in number. The problem of too many post-ghosts and of too much differential delay between those ghosts can be solved by using an IIR filter with a greater number of taps with non- zero weighting and an increased number of programmable bulk delay devices. The problem of too many preghosts and of too much differential delay between those ghosts can be solved by using a FIR filter of more complex design. When there are both post-ghosts and preghosts to be suppressed, however. the problem of poor ghost suppression is not solved by dealing with the post-ghost problem and with the preghost problem separately.

The inventors have observed that ghost suppression is good when conditions are such that one of the cascaded filters has substantially no effect on the response of the other. The problem is that when there are both post-ghosts and preghosts to be suppressed, the IIR and FIR filter responses are interactive with each other. By way of illustrating this interaction, suppose the IIR filter precedes the FIR filter in their cascade connection with each other. For each post- ghost cancell d by th IIR filter, a preghost supplied to that filter will giv rise to a ghost of the pre-ghost. The ghost of the pre-ghost is delayed from th preghost by the same interval as the suppressed post-ghost was delayed from the predominant signal.

In ghost-suppression circuitry preferred for use with the methods of the invention, ghosts accompanying composite video signal from the video detector

in a television rec iver or a video tape recorder are suppressed in the cascade connection of three digital filters having filtering parameters adjustable in response to digital programming signals: one, an IIR filter used for suppressing trailing macroghosts. or post-ghosts; another, an FIR filter used for suppressing leading macroghosts, or preghosts; and still another, a further FIR filter used for suppressing microghosts, or "equalizing" reception channel response. The filtering parameters of these three digital filters are calculated in certain methods embodying the invention in various different aspects.

These methods each include data acquisition and channel characterization steps followed by a decision step comparing the most recent set of channel characterization results with the next most recent set of channel characterization results to determine whether stable ghosting conditions obtain. This decision step loops the method back through the data acquisition and channel characterization steps until stable ghosting conditions obtain, so the most recent set of channel characterization results can be relied upon to support accurate calculations in subsequent steps of calculating the filtering parameters for the IIR filter used for suppressing trailing macroghosts and the FIR filter used for suppressing leading macroghosts.

After the steps of calculating the filtering parameters for the filters used for suppressing macroghosts, each of these methods performs a step of calculating the filtering parameters for the FIR filter used for suppressing microghosts. This step is followed by further data acquisition and further channel characterization steps, followed by a decision step comparing the most recent set of further channel characterization results with the next most recent set of further channel characterization results to determine whether they are substantially the same. If the sets of further channel characterization results are substantially the same, either method loops back to the further data acquisition step; if the sets differ appreciably, either method resets the adjustable filtering parameters for the filters to initial values and the method restarts automatically.

Two methods embodying the invention in somewhat different aspects each perform the initial calculations of the adjustable filtering parameters of the IIR filter used for suppressing trailing macroghosts independently of the initial calculations of the adjustable filtering parameters of the FIR filter used for suppressing leading macroghosts. This initially-separabl calculation technique reduces the amount of calculations considerably-over previously known techniques, even taking into account the subsequent calculations that are sometimes needed to correct the separable calculations. In one preferred method, a successive-approximation method, subsequent calculations to provid this correction are arranged for by looping back to the data acquisition and channel char-

acterization steps and recalculating the adjustable filtering parameters of the filters used for suppressing macroghosts until the macroghosts are reduced below a prescribed threshold level. In another method, which does not depend on successive approximations, the subsequent calculations to provide this correction are based on the fact that the DFT of the correction corresponds in prescribed manner to the DFT of the convolution of the frequency responses of the filters used for suppressing macroghosts.

More specifically, according to one aspect of the present invention, there is provided a method of operating apparatus comprising a receiver for receiving through a reception channel a video signal with accompanying ghost-cancelling reference (GCR) signal both subject at times to being ghosted; a ghost-suppression filter connected for responding to said video signal, said ghost-suppression filter having adjustable filtering parameters; a computer for calculating the adjustable filtering parameters of said ghost-suppression filter, said computer being provided with a read-only memory for permanently storing data descriptive of ghost-free GCR signal and with further memory for purposes of temporary storage; and a GCR-signal separator for separating from the response of said ghost-suppression filter to said video signal the response of said ghost- suppression filter to said received GCR signal, subject at times to being ghosted, to supply a separated GCR signal; said method avoiding the erroneous adjustment of the filtering parameters of said ghost-suppression filter during non-stable ghosting conditions such as "aircraft flutter" and comprising the steps of:

a.) initializing the adjustable filtering parameters of said ghost- suppression filter;

b.) loading said separated GCR signal into said further memory of said computer, for purposes of temporary storage, which loading is done after step (a.) and can be done after other steps in the method as prescribed hereafter in this claim or any claim depending therefrom;

c.) each time after step (b.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that step (b.) to generate a set of updated channel characterization results;

d.) each time after step (c.) is performed, temporarily storing within the further memory of said computer the set of updated channel characterization results generated by that step (c.);

e.) each time after step (c.) is performed, determining within said computer wheth r or not ghosting conditions have changed, by comparing each portion of the updated set of channel characterization results with the corresponding porti n of the previously temporarily stored set of channel characterization results, ghosting condi-

tions being determined not to have changed only when corresponding portions of the compared sets of channel characterization r sults in every comparison differ by less than a first threshold value, the method looping back to step (b.) when ghosting conditions are determined to have changed when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or more than said first threshold value; and

f.) each time ghosting conditions are determined not to have changed when step (e.) is performed, thereafter performing calculations within said computer for determining the adjustable filtering parameters for said ghost-suppression filter.

According to another aspect of the present invention, there is provided a method of operating apparatus comprising a receiver for receiving through a reception channel a video signal with accompanying ghost-cancelling reference (GCR) signal both subject at times to being ghosted; a ghost-suppression filter connected for responding to said video signal which ghost-suppression filter comprises in a cascade connection a first filter of a type having adjustable filtering parameters that can be adjusted for suppressing macroghosts in its output response and a second filter of a type having adjustable filtering parameters that can be adjusted for suppressing microghosts in its output response; a computer for calculating the adjustable filtering parameters of said second filters, said computer being provided with a read-only memory for permanently storing data descriptive of ghost-free GCR signal and with further memory for purposes of temporary storage; and a GCR-signal separator for separating from the response of said ghost-suppression filter to said video signal the response of said ghost-suppression filter to said received GCR signal, subject at times to being ghosted, to supply a separated GCR signal: said method comprising the steps of:

a.) initializing the adjustable filtering parameters of said first and second filters;

b.) loading said separated GCR signal into said further memory of said computer, for purposes of temporary storage, which loading is done after step (a.) and can be done after other steps in the method as prescribed hereafter in this claim or any claim depending therefrom;

c.) each time after step (b.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that st p (b.) to generate a set of updat d chann l characterization results;

d.) each time after step (c.) is performed, temporarily storing within the further memory of said computer the set of updated channel charact ri zation r sults g nerated by that step (c.);

e.) each time after step (c.) is performed, determining within said computer whether or not ghosting conditions hav changed, by comparing each portion of the updated set of channel characterization results with the corresponding portion of the previously temporarily stored set of channel characterization results, ghosting conditions being determined not to have changed only when corresponding portions of the compared sets of channel characterization results in every comparison differ by less than a first thresh ld value, the method looping back to step (b.) when ghosting conditions are determined to have changed when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or more than said first threshold value:

f.) each time ghosting conditions are determined not to have changed when step (e.) is perform d, thereafter performing calculations within said computer for determining the adjustable filtering parameters for said first filter;

g.) after step (f.) has been performed so that the adjustable filtering parameters for said first filter satisfactorily reduce all ghosts in the updated separated GCR signal, performing calculations within said computer for determining the adjustable filtering parameters for said second filter;

h.) after step (g.) has been performed, loading an updated separated GCR signal into said further memory of said computer, for purposes of temporary storage;

i.) each time after step (h.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that step (h.) to generate a set of updated channel characterization results;

j.) each time after step (i.) is performed, temporarily storing within the further memory of said computer the set of updated channel characterization results generated by that step (i.); and

k.) each time after step (i.) is performed, determining within said computer whether or not ghosting conditions have changed, by comparing each portion of the updated set of channel characterization results with the corresponding portion of the previously temporarily stored set of channel characterization results, ghosting conditions being determined not to have changed only when corresponding portions of the compared sets of channel characterization results in very comparison differ by less than a second threshold value, the method looping back to step (a.) when ghosting conditions are determined to have changed when corresponding portions of the compar d sets of channel characterization results in any of said comparisons differ by as much

as or more than said second threshold value.

Preferably, each of the steps (c.) and (i.) comprises the substeps of:

using said computer to calculate the DFT of said separated GCR signal loaded into said computer in the just previous step; and

then using said computer to divide the terms of the DFT of said separated GCR signal by the corresponding terms of the DFT of said ghost-free GCR signal stored in said permanent memory and read therefrom, thereby to generate the DFT of said reception channel, the terms of the DFT of said reception channel comprising the set of channel characterization results generated by the step.

Preferably, step (f.) comprises the substeps of:

fa.) using said computer to determine the largest term of the DFT characterizing the response of said reception channel as read from the further memory of said temporary memory in said computer;

fb.) after substep (fa.), using said computer for dividing all of the terms of the DFT characterizing the response of said reception channel by the largest term, thereby to generate the terms of a normalized DFT characterizing the response of said reception channel;

fc.) after substep (fb), using said computer for replacing by a respective zero each of the terms of the normalized DFT that are smaller than a threshold value, thereby to generate an approximated normalized DFT characterizing the response of said reception channel;

fd.) after substep (fc), using said computer for complementing all of the non-zero terms of said approximated normalized DFT characterizing the response of said reception channel except for its largest, thereby to generate the DFT of said first filter; and

fe.) after substep (fd), using said computer for calculating the adjustable filtering parameters for said first filter from its DFT.

Preferably,in the step (g.) the substep of performing calculations within said computer for determining the adjustable filtering parameters for said second filter is carried out with the following substeps:

ga.) taking from said further memory terms of a truncation of the DFT of said separated GCR signal most recently computed and temporarily stored;

gb.) using said computer to divide the terms of th truncated DFT of said separated GCR signal portion by the corresponding terms of the DFT of a corresponding portion of said ghost-fre GCR signal stored in said permanent memory and read therefrom, thereby to generat a truncated DFT of said reception chann l;

gc.) generating with said computer the DFT of

said second filter so as to complement the truncated DFT of said reception channel;

gd.) d termining with said computer updated values for the adjustable filtering parameters of said second filter in accordance with its DFT; and

ge.) applying the updated adjustable filtering parameters to said second filter.

Preferably, in the step (g.) the substep of performing calculations within said computer for determining the adjustable filtering parameters for said second filter is carried out with the following substeps:

ga.) reading from said further memory of said computer, the DFT of said separated GCR signal most recently computed and temporarily stored;

gb) calculating with said computer a first truncated DFT, which is of the convolution of the response of said second filter with said separated GCR signal most recently computed and temporarily stored;

gc.) reading from said permanent memory of said computer, terms of a second truncated DFT, which is of the ghost-free GCR signal as convolved by a desired reception channel response;

gd.) determining with said computer the departures of the terms of said first truncated DFT from the corresponding terms of the second truncated DFT; and

ge.) responding to each said departure for adjusting the corresponding adjustable filtering parameter for said second filter in a direction to reduce that departure.

According to a further aspect of the present invention, there is provided a method of operating apparatus comprising a receiver for receiving through a reception channel a video signal with accompanying ghost-cancelling reference (GCR) signal both subject at times to being ghosted; an IIR filter of a type having adjustable filtering parameters that can be adjusted for suppressing in its output response trailing macroghosts or post-ghosts accompanying its input signal; an FIR filter of a type having adjustable filtering parameters that can be adjusted for suppressing in its out put response leading macroghosts or preghosts accompanying its input signal;

a ghost-suppression filter connected for responding to said video signal which ghost-suppression filter comprises the cascade connection of said IIR filter and said FIR filter;

a computer for calculating the adjustable filtering parameters of said first and said second digital filters, said computer being provid d with a r ad-only memory for permanently storing data descriptive of ghost-free GCR signal and with further m mory for purposes of temporary storage; and

a GCR-signal separator for separating from the response of said ghost-suppression filter to said video signal the respons of said ghost-suppression

filter to said received GCR signal, subject at times to being ghosted, to supply a separated GCR signal: said method comprising the steps f:

a.) initializing the adjustable filtering parameters of said first and second digital filters;

b.) loading said separated GCR signal into said further memory of said computer, for purposes of temporary storage, which loading is done after step (a.) and can be done after other steps in the method as prescribed hereafter in this claim or any claim depending therefrom;

c.) each time after step (b.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that step (b.) to generate a set of updated channel characterization results;

d.) each time after step (c.) is performed, temporarily storing within the further memory of said computer the set of updated channel characterization results generated by that step (c.);

e.) each time after step (c.) is performed, determining within said computer whether or not ghosting conditions have changed, by comparing each portion of the updated set of channel characterization results with the corresponding portion of the previously temporarily stored set of channel characterization results, ghosting conditions being determined not to have changed only when corresponding portions of the compared sets of channel characterization results in every comparison differ by less than a first threshold value, the method looping back to step (b.) when ghosting conditions are determined to have changed when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or more than said first threshold value;

f.) each time ghosting conditions are determined not to have changed when step (e.) is performed, thereafter performing calculations within said computer for determining the adjustable filtering parameters for said IIR filter and said FIR filter in the cascade connection which said ghost-suppression filter comprises;

g.) after step (f.) has been performed so that the adjustable filtering parameters for said IIR filter and said FIR filter satisfactorily reduce all ghosts in the updated separated GCR signal, proceeding from step (f.) to step (h.);

h.) loading an updated separated GCR signal into said further memory of said computer, for purposes of temporary storage;

i.) each time after step (h.) Is performed, performing calculations within said comput r for charact rizing the reception channel as described by the separated GCR signal loaded into said computer during that step (h.) to generat a set of updated channel characterization results;

j.) each time after step (i.) is performed, temporarily storing within the further memory of said computer the set of updated channel characterization results generated by that step (i.); and

k.) each time after step (i.) is performed, determining within said computer whether or not ghosting conditions have changed, by comparing each portion of the updated set of channel characterization results with the corresponding portion of the previously temporarily stored set of channel characterization results, ghosting conditions being determined not to have changed only when corresponding portions of the compared sets of channel characterization results in every comparison differ by less than a second threshold value, the method looping back to step (a.) when ghosting conditions are determined to hav changed when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or more than said second threshold value.

In a method as set forth above, 7 for operating said apparatus when the cascade connection of said IIR filter and said FIR filter in said ghost-suppression filter further includes a further FIR filter for suppressing microghosts, the step (g.) of proceeding from step (f.) to step (h.) may comprise the substeps of:

performing calculations within said computer for determining updated adjustable filtering parameters for said further FIR filter; and

applying said updated adjustable filtering parameters to said further FIR filter.

Preferably, in the step (g.) the substep of p r-forming calculations within said computer for determining the adjustable filtering parameters for said further FIR filter is carried out with the following substeps:

ga.) taking from said further memory terms of a truncation of the DFT of said separated GCR signal most recently computed and temporarily stored;

gb.) using said computer to divide the terms of the truncated DFT of said separated GCR signal portion by the corresponding terms of the DFT of a corresponding portion of said ghost-free GCR signal stored in said permanent memory and read therefrom, thereby to generate a truncated DFT of said reception channel;

gc.) generating with said computer the DFT of said further FIR filter so as to complement the truncated DFT of said reception channel;

gd.) determining with said computer updated values for the adjustable filtering parameters of said further FIR filter in accordance with its DFT; and

ge.) applying to said further FIR filter the updated adjustable filtering parameters for said furth r FIR filter.

Preferably, in the step (g.) the substep of performing calculations within said computer for determining the adjustable filtering parameters for said further FIR filter is carried out with the following substeps:

ga.) reading from said further memory of said computer, the DFT of said separated GCR signal most recently computed and temporarily stored;

gb) calculating with said computer a first truncated DFT, which is of the convolution of the response of said second filter with said separated GCR signal most recently computed and temporarily stored;

gc.) reading from said permanent memory of said computer, terms of a second truncated DFT, which is of the ghost-free GCR signal as convolved by a desired reception channel response;

gd.) determining with said computer the departures of the terms of said first truncated DFT from the corresponding terms of the second truncated DFT; and

ge.) responding to each said departure for adjusting the corresponding adjustable filtering parameter for said second filter in a direction to reduce that departure.

Preferably, said step (f.) comprises the substeps of:

fa.) on a separable basis, calculating within said computer adjustable filtering parameters for said IIR filter; and

fb.) on a separable basis, calculating within said computer adjustable filtering parameters for said FIR filter.

In said step (f.), said substep of calculating adjustable filtering parameters for said IIR filter may be performed before said substep of calculating adjustable filtering parameters for said FIR filter.

In said step (f.) said substep of calculating adjustable filtering parameters for said IIR filter may be performed after said substep of calculating adjustable filtering parameters for said FIR filter.

Preferably, said step (f.) further comprises the substeps of:

fc.) applying to said IIR filter said adjustable filtering parameters calculated in substep (fa.), before any correction of said adjustable filtering parameters for said IIR filter calculated in said substep;

fd.) applying to said FIR filter said adjustable filtering parameters calculated in substep (fb.), before any correction of said adjustable filtering parameters for said FIR filter calculated in said substep;

f .) determining wheth r or not th adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below said first threshold valu ;

ff.) counting the determinations that the adjustable filtering paramet rs of said IIR filter and said FIR filter require adjustm nt in the current step (f.) in order to reduce all ghosts below a prescribed third threshold value, the count being initially zero and being reset to zero whenever there is a determination that the adjustable filtering parameters of said IIR filter and said FIR filter do not require adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value; and

fg.) looping back to step (b.) responsive to said count being below a prescribed count and the determination that the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below said threshold value.

Preferably, said step (f.) further comprises the substeps of:

fc.) calculating with said computer corrections for the adjustable filtering parameters of said IIR filter and said FIR filter;

fd.) making said corrections to the adjustable filtering parameters of said IIR filter and said FIR filter; and

fe.) applying to said IIR filter and said FIR filter the resulting corrected adjustable filtering parameters, whereupon the step (f.) has been performed so that the adjustable filtering parameters for said IIR filter and said FIR filter satisfactorily reduce all ghosts in the updated separated GCR signal.

Preferably, step (f.) comprises the substeps of:

fa.) using said computer to determine the largest term of the DFT characterizing the response of said reception channel as read from the further memory of said temporary memory in said computer;

fb.) after substep (fa.), calculating with said computer the adjustable filtering parameters of said IIR filter from the smaller terms of the DFT characterizing the response of said reception channel later in time than the largest term of the DFT characterizing the response of said reception channel, which smaller terms of the DFT characterizing the response of said reception channel later in time than the largest term of the DFT characterizing the response of said reception channel exceed a prescribed threshold value; and

fc.) after substep (fa), calculating with said comput r the adjustable filtering parameters of said FIR filter from the smaller terms of the DFT characterizing th response of said reception channel earlier in time than the largest term of the DFT charact rizing th respons of said reception chann l, which smaller terms of the DFT characterizing the respons of said reception channel

earlier in time than the largest term of the DFT characterizing the response of said reception channel exceed a prescrib d threshold valu .

Preferably, said step (f.) further comprises the substeps of:

fd.) applying to said IIR filter said adjustable filtering parameters calculated in said substep (fb.);

fe.) applying to said FIR filter said adjustable filtering parameters calculated in said substep (fc.);

ff.) determining whether or not the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value;

fg.) counting the determinations that the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below a prescribed third threshold value, the count being initially zero and being reset to zero whenever there is a determination that the adjustable filtering parameters of said IIR filter and said FIR filter do not require adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value;

fh.) looping back to step (b.) responsive to said count being below a prescribed count and the determination that the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in substep (ff.) of the current step (f.) in order to reduce all ghosts below said threshold value.

Said step (f.) may further comprise the substeps of:

fd.) calculating with said computer corrections for the adjustable filtering parameters of said IIR filter and said FIR filter;

fe.) making said corrections to the adjustable filtering parameters of said IIR filter and said FIR filter: and

ff) applying to said IIR filter and said FIR filter the resulting corrected adjustable filtering parameters, whereupon the step (f.) has been -performed so that the adjustable filtering parameters for said IIR filter and said FIR filter satisfactorily reduce all ghosts in the updated separated GCR signal.

Preferably, each of the steps (c.) and (i.) comprises the substeps of:

using said computer to calculate the DFT of said separated GCR signal loaded into said computer in the just previous step; and

then using said computer to divide the terms of the DFT of said separated GCR signal by the corresponding terms of th DFT of said ghost-free GCR signal stored in said permanent memory and r ad therefrom, thereby to generate the DFT of said reception channel, the terms of the DFT of said r ception

channel comprising the set of channel characterization r sults generated by the step.

According to another aspect of the present invention, there is provided a method of operating apparatus comprising a receiver for receiving through a reception channel a video signal with accompanying ghost-cancelling reference (GCR) signal both subject at times to being ghosted;

an IIR filter of a type having adjustable filtering parameters that can be adjusted for suppressing in its output response trailing macroghosts or post-ghosts accompanying its input signal;

a first FIR filter of a type having adjustable filtering parameters that can be adjusted for suppressing in its output response leading macroghosts or preghosts accompanying its input signal;

a second FIR filter of a type having adjustable filtering parameters that can be adjusted for suppressing in its output response microghosts accompanying its input signal;

a ghost- suppression filter connected for responding to said video signal which ghost-suppression filter comprises the cascade connection of said IIR filter, said first FIR filter, and said second FIR filter;

a computer for calculating the adjustable filtering parameters of said first and said second digital filters, said computer being provided with a read-only memory for permanently storing data descriptive of ghost-free GCR signal and with further memory for purposes of temporary storage; and

a GCR-signal separator for separating from the response of said ghost-suppression filter to said video signal the response of said ghost-suppression filter to said received GCR signal, subject at times to being ghosted, to supply a separated GCR signal; said method comprising the steps of:

a.) initializing the adjustable filtering parameters of said first and second digital filters;

b.) loading said separated GCR signal into said further memory of said computer, for purposes of temporary storage, which loading is done after step (a.) and can be done after other steps in the method as prescribed hereafter in this claim or any claim depending therefrom;

c.) each time after step (b.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that step (b.) to generate a set of updated channel characterization results;

d.) each time after step (c.) is performed, temporarily storing within the further memory of said computer the set of updated chann l characterization results generat d by that step (c.);

e.) each time after step (c.) is performed, determining within said computer wheth r or not ghosting conditions have changed, by comparing

each portion of the updated set of channel characterization r sults with the corresponding portion of the previously temporarily stored set of channel characterization results, ghosting conditions being determined not to have changed only when corresponding portions of the compared sets of channel characterization results in every comparison differ by less than a first threshold value, the method looping back to step (b.) when ghosting conditions are determined to have changed when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or more than said first threshold value;

f.) each time ghosting conditions are determined not to have changed when step (e.) is performed, thereafter performing calculations within said computer for determining the adjustable filtering parameters for said IIR filter, said first FIR filter and said second FIR filter in the cascade connection which said ghost- suppression filter comprises;

g.) after step (f.) has been performed so that the adjustable filtering parameters for said IIR filter, said first FIR filter and said second FIR filter satisfactorily reduce all ghosts in the updated separated GCR signal, proceeding from step (f.) to step (h.);

h.) loading an updated separated GCR signal into said further memory of said computer, for purposes of temporary storage;

i.) each time after step (h.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that step (h.) to generate a set of updated channel characterization results;

j.) each time after step (i.) is performed, temporarily storing within the further memory of said computer the set of updated channel characterization results generated by that step (i.); and

k.) each time after step (i.) is performed, determining within said computer whether or not ghosting conditions have changed, by comparing each portion of the updated set of channel characterization results with the corresponding portion of the previously temporarily stored set of channel characterization results, ghosting conditions being determined not to have changed only when corresponding portions of the compared sets of channel characterization results in very comparison differ by less than a second threshold value, the method looping back to step (a.) when ghosting conditions are determin d to have chang d when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or mor than said s cond threshold value.

Preferably, said step (f.) comprises the substeps of:

fa.) calculating with said computer adjustable filtering parameters for said IIR filter on a separable basis and applying them to said [IR filter;

fb.) calculating with said computer adjustable filtering parameters for said first FIR filter on a separable basis and applying them to said first FIR filter;

fc.) calculating with said computer adjustable filtering parameters for said second FIR filter on a separable basis and applying them to said second FIR filter;

fd.) determining whether or not the adjustable filtering parameters of said IIR filter, said first FIR filter and said second FIR filter required adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value;

fe.) counting the determinations that the adjustable filtering parameters of said IIR filter, said first FIR filter and said second FIR filter required adjustment in the current step (f.) in order to reduce all ghosts below a prescribed first threshold value, the count being initially zero and being reset to zero whenever there is a determination that the adjustable filtering parameters of said IIR filter and said FIR filter do not require adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value;

fg.) looping back to step (b.) responsive to said count being below a prescribed count and the determination that the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below said threshold value.

In said step (f.), said substep (fa.) may performed before said substep (fb.).

In said step (f.), said substep (fa.) may be performed after said substep (fb.).

Preferably, said substep fc.) comprises the substeps of:

reading from said further memory of said computer, the DFT of said separated GCR signal most recently computed and temporarily stored; calculating with said computer a first truncated DFT, which is of the convolution of the response of said second filter with said separated GCR signal most recently computed and temporarily stored;

reading from said permanent memory of said computer, terms of a second truncated DFT, which is of the ghost-fre GCR signal as convolved by a desired reception channel response;

determining with said computer th departures of the terms of said first truncated DFT from the corresponding terms of the second truncated DFT; and

responding t each said departure for updating th corresponding adjustabl filtering parameter

for said second filter with its previous value as incremented or decremented by an adjustment which is in a direction to reduce that departure and which has an amplitude that is a prescribed fraction of that departure.

The invention extends to an apparatus as recited in any of the preceding aspects of the invention, adapted to perform a method as set forth therein.

Such an apparatus may comprise a televison and/or video recorder and/or player.

For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings, in which:

Figure 1 is a general schematic diagram of a system, comprising a TV receiver or video tape recorder with ghost- suppression circuitry in which methods of the invention may be usefully employed;

Figure 2 is a schematic diagram of ghost-suppression circuitry suitable for inclusion in the Figure 1 combination, which ghost-suppression circuitry includes GCR signal acquisition circuitry;

Figure 3 is a schematic diagram of circuitry for resetting a modulo-eight field counter in the Figure 2 ghost-suppression circuitry;

Each of Figures 4, 5 and 6 is a flow chart of one of two alternative deghosting methods that can be used with the Figure 2 deghosting circuitry, which method embodies the invention in one of its aspects;

Figure 7 is a flow chart of substeps that can be performed in carrying out step 84 of the Figure 4, Figure 5 or Figure 6 method;

Figure 8 is a flow chart of substeps that can be performed in a first way of carrying out step 90 of the Figure 4 method or of the Figure 6 method;

Figure 9 is a schematic diagram of one way of implementing a sparsely weighted IIR filter, as can be used in methods of the invention for suppressing trailing macroghosts, or post-ghosts;

Figure 10 is a schematic diagram of one way of implementing a sparsely weighted FIR filter, as can be used in methods of the invention for suppressing leading macroghosts, or preghosts;

Figure 11 is a more detailed flow chart of substeps that can be performed for calculating the filtering parameters for ghost-cancelling filters formed from the cascade connection of a sparsely weight d IIR filter and a sparsely weighted FIR filter, wh n carrying out steps 96 and 97 of the Figure 5 method;

Figure 12 is a flow chart of substeps that can be perform d in carrying out step 94 of the Figur 5 method: and

Figure 13 is a more detail d flow chart of sub-

steps that can be performed for calculating corrections for "filter-generated" ghosts, when carrying out the step 98 of the Figure 5 method;

Various modifications that can be made to the circuitry shown in Figures 2 and 3 are noted within parentheses in those figures.

In the figures, like reference numerals denote like or corresponding parts.

The term "television set" is used in this specification to describe a television receiver front end with accompanying kinescope, power supply for a kinescope, deflection circuitry for a kinescope, portions of a television receiver associated with converting the composite video signal to the color signals for driving a kinescope, loudspeaker(s), stereophonic sound d - tector or audio amplication circuitry. The conventional video cassette recorder (VCR) includes a television receiver front end without those accompanying further items, which are termed a "television monitor" in this specification and the accompanying drawings. If in a VCR and TV-set combined into a single piece of apparatus called a "combo", one desires the capability simultaneously to record a program received on one channel and to display a program received on a different channel, two TV receiver front ends have to be provided, one for the video tape machine with recording capability and one for the television receiver with image displaying capability. As taught in U.S. Patent Application Serial No. 07/955,016 filed for Chandrakant B. Patel and Min Hyung Chung on 1 October 1992, entitled VIDEO TAPE RECORDER WITH TV RECEIVER FRONT END & GHOST-SUPPRESSION CIRCUITRY, and assigned to Samsung Electronics Company, Limited, it is preferable to include respective sets of ghost-cancellation circuits after the video detectors of each of these TV receiver front ends, although one microcomputer can be us d for calculating the filtering parameters for both sets of ghost- cancellation circuits.

Raster-scanning maps the two-dimensional spatial domains of successive image fields, which form a three-dimensional domain in space and time, into the one-dimensional time domain of a video signal. Television engineers refer to filter networks that combine various sample values of the video signal by names suggestive of the results of such combining in the three-dimensional domain in space and time. A filter network combining the sample values of the video signal which describe picture elements or "pixels" arrayed along the scan line of an image field is referred to as a "horizontal spatial filter". A filter network combining the sample values of the video signal separated in time by scan line intervals, which samples describe pixels that are arrayed transv rsely to the scan lines of an image field, is referred to as a "vertical spatial filter". A filter network combining the values of samples of the video signal separated in time by scan line intervals, which samples describe

pixels that appear in the same position in successive image fields or frames, is referred to as a "temporal filter" — i.e. a filter that operates in the time dimension rather than either of the spatial dimensions. A temporal filter may combine pixels for only one position in space, but commonly combines correspondingly-located pixels from a plurality of frames for each of several positions in space. E.g., in a line-averaging filter correspondingly-located pixels are averaged for each of the positions along a scan line. By analogy, as used in this specification or the claims which follow, the term "temporal filter" is to be understood to include filters for combining corresponding "pixels" of respective scan lines selected from consecutive fields which scan lines include GCR signals. This particular type of temporal filter is referred to as a "GCR-signal- averaging filter" in this specification and the claims which follow, although averaging is not done on an actual-value basis, but only after correcting to a standard polarity of chirp.

Memories providing temporary storage of a number of samples corresponding to pixel positions in a scan line of video signal are referred to in this specification as "temporary 1-line stores" even though such stores may in fact be included in accumulators that accumulate several lines on a pixel-by-pixel basis. Similarly, memories providing temporary storage of a number of samples corresponding to pixel positions in two consecutive scan lines of video signal are referred to in this specification as "temporary 2-line stores" even though such stores may in fact be included in accumulators that accumulate several pairs of consecutive lines on a pixel-by-pixel basis. The inclusion of several temporary 1-line stores or temporary 2-line stores within a single banked memory is, of course, within the scope of the invention disclosed in this specification and its accompanying drawings.

A television receiver front end 20, in response to a radio- frequency television signal received thereby, supplies a sound signal and a composite video signal to apparatus 10, which apparatus 10 may be a television monitor or may be a video tape machine receiving these signals for recording. The video tape machine having recording capability may be a video cassette recorder (VCR) of VHS, super-VHS or Betamax type. By way of further example, the video tape machine may be an improved VHS recorder of the type described in U.S. Patent No. 5.113,262 issued 12 May 1992 to C.H. Strolle et al and entitled "VIDEO SIGNAL RECORDING SYSTEM ENABLING LIMITED BANDWIDTH RECORDING AND PLAYBACK".

Th radio-frequ ncy t levision signal may be broadcast over the air and then captur d by an aerial tel vision antenna 30 for application to the television rec iver front end 20, as shown by way of example. Alternatively, the radio-frequency t levision signal can be provided over cable by community-antenna or other t levision cable service. Th tel vision receiv r

front end 20 includes the portions of a conventional television receiv r normally employed in combination, either with a television monitor for displaying the video image, or with a video tape machine having recording capability. These portions generally include a radio-frequency amplifier, a down converter or "first detector", at least one intermediate-frequency amplifier, a video detector or "second detector", and a sound demodulator (frequently of intercarrier type). The television receiver front end 20 further includes separation circuitry for horizontal synchronizing pulses and for vertical synchronizing pulses.

The sound signal from the sound demodulator in the television receiver front end 20 is demodulated from a frequency-modulated sound carrier, as heterodyned to intermediate frequency by the down converter. Before its demodulation the frequency-modulated sound carrier is limited to remove amplitude variations therein, and the capture phenomenon suppresses responses to ghosts in the sound signal from the sound demodulator. Accordingly, the sound signal from the sound demodulator in the television receiver front end 20 is supplied directly to the apparatus 10, there to be utilized in a conventional manner.

The composite video signal from the video detector in the television receiver front end 20 is supplied to ghost-suppression circuitry 40 to have the accompanying ghosts removed or suppressed. The ghost-suppression circuitry 40, which can be any one of the types known to the art, includes adaptive filter circuitry and a computer for calculating the filter parameters for that adaptive filter circuitry. The resulting "deghosted" composite video signal is supplied from the ghost-suppression circuitry 40 to the apparatus 10, there to be utilized in a conventional manner. A GCR-signal separator (or GCR-signal acquisition circuitry) 45 selects a GCR signal and attendant ghosted replicas thereof from the composite video signal from the video detector in the television receiver front end 20. The GCR-signal separator 45 supplies the ghosted GCR signal it separates to the computer in the ghost-suppression circuitry 40, in which computer the ghosted GCR signal is correlated with a priori information concerning a ghost-free GCR signal as a basis for calculating the filter parameters for the adaptive filter circuitry in the ghost-suppression circuitry 40. In preferred embodiments of the invention the GCR-signal separator 45 takes the form of GCR-signal acquisition circuitry that averages on a pixel-by-pixel basis the Bessel chirps as extracted from the GCR signals in a number of consecutive fields. The GCR signals including ETP chirps form a first set of GCR signals, and th GCR signals including ETR chirps form a second s t of GCR signals.

Rapidly changing multipath conditions occur at times — such as when one or more aircraft fly over the television receiver antenna 30, for example, causing fast-changing selective fading referred to as "aircraft

flutter". The filter-coefficient computer within the ghost-suppression circuitry 40 generally is one with sufficient spe d to compute updated filter parameters within a field time. However, the multipath conditions may change so rapidly during aircraft flutter, that updated filter parameters calculated just from one ghosted GCR signal selected from the 19th line of a field are no longer appropriate at the later time in the field when the calculations of those filter parameters are completed. When in accordance with preferred embodiments of the invention noise-reduced GCR signals are generated by averaging the GCR signals from several consecutive fields, the calculation of updated filter parameters is even less able to track the rapidly changing multipath conditions. Accordingly, currently, it is most practical to determine the filter parameters for the ghost-suppression circuitry 40 only after the rapidly changing multipath conditions have passed and static multipath conditions are re-established.

Figure 2 illustrates one form the ghost-suppression circuitry 40 can take, which is suited for use with the Bessel-chirp GCR signals being inserted into the 19th VBI lines of each field. A composite video signal, supplied to the Figure 2 ghost-suppression circuitry from the television receiver front end 20, is digitized by an analog-to-digital converter 50. The ADC 50 typically will supply eight-parallel-bit samples of digitized composite video signal. The digitized composite video signal is applied as input signal to a cascade connection of a post-ghost-cancellation filter 51, which is an adaptive filter of IIR type; a pre-ghost cancellation filter 52, which is an adaptive filter of FIR type; and an equalization filter 53, which is an adaptive filter of FIR type.

The output signal of the filter cascade is a digital deghosted composite video signal, which is converted to an analog deghosted composite video signal by a digital-to-analog converter 54. The analog deghosted composite video signal is supplied to the apparatus 10. The digital-to-analog converter 54 is dispensed with in advanced designs where the apparatus 10 is of a type utilizing digital, rather than analog signals.

A filter coefficient computer 55 computes the weighting coefficients for the adaptive filters 51, 52 and 53. These weighting coefficients are binary numbers, which the filter-coefficient computer 55 writes into registers within the digital filters 51, 52 and 53. In the IIR filter 51 the weighting coefficients stored in registers thereof are used as multiplier signals for digital multipliers receiving the filter output signal with various amounts of delay as multiplicand signals. The product signals from the digital multipliers are algebraically combined in digital adder/subtractor circuitry to generate the IIR filter response. In each of the FIR filt rs 52 and 53 the weighting coefficients stored in registers th reof are used as multiplier signals for digital multipliers receiving the filter input signal with various amounts of delay as multiplicand signals. In each of the FIR filt rs 52 and 53 the product signals from the digital multipliers are algebraically combined in digital adder/subtractor circuitry to generate the weighted summation response characteristic of an FIR filter.

Preghosts occurring in off-the-air reception can be displaced as much as 6 microseconds from the direct signal, but typically, displacements are no longer than 2 microseconds. In cable reception, direct off-the-air pick-up can precede the cable-supplied signal by as much as 30 microseconds. The number of taps in the FIR filters 52 and 53 depends on the range over which ghost suppression is sought. To keep filter costs within commercial constraints, typically the FIR filter 52 has around 64 taps for suppressing ghosts with as much as 6 microseconds displacement from the direct signal. The FIR filter 53 used for frequency equalization need only have 32 taps or so. The FIR filter 53 is typically required to correct in-band video response that can be rolled off by as much as 20 dB at 3.6 MHz, but roll-off at 3.6 MHz is usually less than 10 dB. The roll- off is usually attributable to incorrect orientation of the antenna in off-the-air reception. The cascaded FIR filters 52 and 53 are replaced in some designs by a single FIR filter having about 80 taps.

Typically, the range for post-ghosts extends to 40 microseconds displacement from the direct signal, with 70% or so of post-ghosts occurring in a subrange that extends to 10 microseconds. The IIR post-ghost cancellation filter 51 required for suppressing post-ghosts over the full range can be as many as 600 taps long. However, since post-ghosts usually are non-overlapping and occur at discrete displacements, the weighting coefficients for many of these taps of the filter 51 are likely to be zero-valued or nearly so. The taps requiring weighting coefficients of value significantly more than zero are clumped together in groups of ten or less except where there are overlapping ghosts. It is desirable, from the standpoint of economy of hardware, to use only as many digital multipliers as there are expected to be weighting coefficients of value significantly more than zero. Accordingly, the tapped delay line in the IIR filter 51 is usually designed as a cascade connection of ten-tap-or-so delay lines interspersed with programmable "bulk" delay devices, making filter 51 what is sometimes termed a "sparse-weighting" filter. The ten-tap-or-so delay lines furnish signals to the digital multipliers for weighting. Th incremental delay between successive taps of each of these ten-tap-or-so delay lines is a single pix l interval. The programmable bulk delay devices each comprise various length d lay lines the chaining together of which can be controlled in response to c ntrol signals expressed as binary numbers. Such a sparse-w ighting filter will includ r g-

isters for the binary numbers specifying the delays of the programmabl d lay devices, the contents of which registers are also controlled by the filter-coefficient computer 55.

The FIR preghost cancellation filter 52 can also be made a sparse-weighting filter and this specification is written to take this possibility into account. Practically speaking, preghosts are generally close-in ghosts and do not precede the principal image much in time, so the FIR preghost cancellation filter 52 will usually not be of sparse-weighting design.

Consider now the means by which the filter-coefficient computer 55 is supplied with ghosted GCR signals from the television receiver front end 20. Horizontal and vertical synchronizing pulses are received from the front end 20. The horizontal sync pulses are counted by a nine-stage digital counter 56, denominat d "scan line counter", periodically reset by vertical sync pulses; and the vertical sync pulses are counted modulo-8 by a three-stage digital counter counter 57, denominated "field counter". These counts are available to the filter-coefficient computer 55 for use in timing its operations, although connections for furnishing these counts to the computer 55 are left out of Figure 2 to reduce its complexity. A decoder 58 responds to the scan line count from the line counter 56 being nineteen, corresponding to the scan line in each field containing GCR signal, to condition the output signal of a multiplexer 59 to correspond to the digitized composite video signal from the output of the cascade connection of filters 51, 52 and 53 supplied as a first input signal thereto, rather than to a wired zero supplied as a zeroth input signal thereto.

The filter-coefficient computer 55 has control over the operating parameters of the filters 51, 52 and 53. So, by manipulation of those operating parameters the computer 55 can select the point in the cascade connection of these filters 51-53 from which GCR signal is separated by the GCR signal separator. (The GCR signal separator comprises the elements 58 and 59 in Figure 2 and the elements 58 and 101-108 in Figure 5.) For example, the input signal applied to the cascade connection of the filters 51-53 can be selected to the GCR signal separator by the computer 55 by setting the weighting coefficients of the recursive paths in the IIR filter 51 to zero values, so the output response of the IIR filter 51 is determined solely by its input signal; by setting to zero all the weighting coefficients except a unity-valued one defining the kernel centre in the FIR filter 52; and by setting to zero all the weighting coefficients except a unity-valued one defining the kernel centre in the FIR filter 53. Alternatively, on can make circuit arrang ments that will implement more direct and faster selection of the point in the cascade connection of the filters 51-53 from which GCR signal is separated. The fact that the point in the cascade connection of th filt rs 51-53 from which GCR signal is separated can be select-

ed is important to understand, since this fact will aid in und rstanding the implementation of th procedure for calculating the variable parameters of the filters 51-53, which is explained further on in this specification with reference to the Figure 4 flow chart.

A random-access memory with read-then-write capability provides a temporary (scan) line store 60 in Figure 2, which store 60 may be replaced by serial memory in alternative embodiments of the ghost-suppression circuitry. This temporary line store 60 is connected in an arrangement for accumulating the 19th-VBL-line GCR signals on a per pixel basis for eight successive fields, in a temporal filtering operation that separates the Bessel-chirp information from other information occurring during those 19th VBI scan lines. Elements 59-69 in the Figure 2 circuitry combine to form a GCR-signal averaging filter that carries out this temporal filtering operation, which correlates the Bessel-chirp information occurring during those 19th VBI scan lines to provide improved signal-to-noise ratio, as compared to using gating simply to separate the Bessel-chirp information from 19th VBI scan lines as it occurs. When the corresponding pixels of the eight GCR signals have been accumulated during the 19th line of FIELD 000, the eighth and last field of the eight-field sequence. the separated Bessel-chirp information is serially loaded one pixel at a time into a register of the filter-coefficient computer 55 during any line of FIELD 000 after its 19th and before the line store 60 is cleared of data. In Figure 2 the line store 60 is cleared of data during the last line of the last field of the eight-field sequence, but this clearance can take place during any line of FIELD 000 after the separated Bessel-chirp information is written into a register of the filter-coefficient computer 55. The transfer of accumulated data from the line store 60 to the computer 55 and the subsequent clearing of the accumulated data from the line store 60 can also take place during any two of the 1st through 18th scan lines of FIELD 001.

More particularly, the temporary line store 60 has to have the capability of storing a full scan line of sixteen-parallel-bit samples, assuming that it is to accumulate (on an algebraic or signed basis) eight lines of eight-parallel-bit samples of digitized composite video signal supplied from the ADC 50 via the cascaded filters 51-53. Two's complement arithmetic is preferred for this signed. algebraic summation. In partial implementation of the arrangement for operating the temporary line store 60 as a signed accumulator for GCR signals, a digital adder/subtractor 61 supplies a sixteen-parallel-bit output signal to the temporary lin store 60 as its write input signal. The digital adder/subtractor 61 receiv s as a first input thereto the output signal of a multiplexer 62, which normally corresponds to the readout from the temporary line store 60 received as the zeroth input of the multiplexer 62. The digital adder/subtractor 61 re-

ceives as a second input thereto the eight- parallel-bit output signal of the multiplexer 59 tog ther with eight wired ZEROs as a sign-bit ext nsion.

A decoder 69 decodes the modulo-eight field count being one, three, six, or zero (i.e. eight) to furnish a logic ZERO to the digital adder/subtractor 61 to condition it to add its input signals. The decoder 69 decodes the modulo-eight field count being two, four, five, or seven to furnish a logic ONE to the digital adder/subtractor 61 to condition it to subtract its second input signal (supplied from the multiplexer 59) from its first input signal (supplied from the multiplexer 62). This arrangement accumulates in the temporary line store 60 the following function:

(FIELD 001 line 19) (FIELD 010 line 19)
+ (FIELD 011 line 19) (FIELD 100 line 19)
- (FIELD 101 line 19) + (FIELD 110 line 19)
- (FIELD 111 line 19) + (FIELD 000 line 19).

During the last line of the eighth field of each sequence of eight fields, the normally ZERO control signal to the multiplexer 62 is caused to be a ONE. This ONE conditions the multiplexer 62 to furnish an output signal corresponding to a first input thereto. which is an arithmetic zero comprising sixteen parallel bits of wired ZEROS. This results in the resetting of the accumulation result in the temporary line store 60 to arithmetic zero. The control signal for the multiplexer 62 is shown in Figure 2 as being generated by a two-input AND gate 63. A decoder 64 decodes the count from the scan line counter 56 corresponding to the last line of the current field to generate one of the input signals to the AND gate 63. A decoder 65 decodes the modulo-eight field count from the counter 57 to generate the other of the input signals to the AND gate 63. The eighth field of each sequence of eight fields generates a 000 modulo-eight count from the field counter 57. Both the input signals to the AND gate 63 are ONE only during the last line of the eighth field of each sequence of eight fields, during which line the AND gate 63 supplies a ONE to the multiplexer 62 as its control signal, causing the accumulation result stored in the temporary line store 60 to be reset to arithmetic zero.

A two-input AND gate 66 supplies a ONE to the filter- coefficient computer 55 when the accumulation result stored in the temporary line store 60 is available for transfer into a ghosted Bessel-chirp register within the internal memory of the computer 55. The output signal of the decoder 65 is one of the input signals to the AND gate 66 and is ONE only during the eighth field of each sequence of eight fields. A two-input NOR gat 67 generates the other of the input signals to th AND gate 66. The NOR gate 67 responds to the output signal of the decoder 64, which detects th last line of a field in the count from line count r 56, and to the output signal of a decod r 68, which detects the vertical blanking interval proceeding from the count from line counter 56. Accordingly,

the NOR gate 67 output signal is ONE except during the vertical blanking interval or during the last line of a field. So, th accumulation r sult stored in the temporary line store 60 is available for transfer into the internal memory of the computer 55 any time during the eighth field of each sequence of eight fields except during its last line or during vertical blanking interval.

The clocking for timing pixel sampling by the analog-to-digital converter 50 and the addressing of the temporary line store 60 will now be considered. An oscillator 70 that has automatic frequency and phase control (AFPC) generates sinusoidal oscillations at the second harmonic of color subcarrier frequency as a primary clocking signal. A zero-crossing detector 71 detects average axis crossings of the sinusoidal oscillations to generate pulses at a rate four times col r subcarrier frequency. These pulses time the sampling of the composite video signal for digitization by the ADC 50; and they would time the advance of data in the temporary line store 60 if it were a serial memory. In the Figure 2 ghost-suppression circuitry the temporary line store 60 is a random-access memory arranged for read-then-write operation as each of its storage locations is addressed. The addresses of its storage locations are recurrently scanned in accordance with the count of pixels supplied from a ten-stage digital counter 72 denominated as "pixel counter", which counts the pulses from the zero-crossing detector 71. These same addresses are supplied to the filter-coefficient computer 55 to be used to address a line storage register therein when separated GCR signal is transferred thereto from the temporary line store 60.

Generally, if it exists, the color burst signal is the most stable frequency reference in a composite video signal and is the preferred reference signal for AFPC of the oscillator 70. The overflow signal from the second stage of the pixel counter 72 is presumably a 3.58 MHz square wave and is supplied as a feedback signal to a first AFPC detector 73 for comparison to a separated burst signal. in order to generate an error signal that an AFPC signal multiplexer 74 selectively applies to the pixel counter 72 for controlling the frequency and phase of its oscillations. A burst gate 75 responds to pulses from a burst gate control signal generator 76 to separate from the analog composite video signal supplied from the TV receiver front end 20 a color burst signal to be supplied to the first AFPC detector 73. The horizontal sync pulses from the television receiver front end 20 are supplied to the burst gate control signal generator 76 and their trailing edges are used to tim th pulses that the generator 76 generat s during color burst intervals. A cascade of astable flip-flops r "one-shots" are customarily employed in the gen ration of these pulses.

The decoder circuitry 68 responds to th scan line counts that the line counter 56 provides which

correspond to the VBI lines in each field to generate an inhibitory signal. This inhibitory signal is applied to the burst gate control signal generator 76 to inhibit its generating pulses, so that the burst gate 75 will select only those backporch intervals during a field which can have color burst. (In a variant embodiment th burst gate control signal generator 76 is not inhibited from generating burst gate pulses during the vertical blanking interval and the time constant of the first AFPC detector is made longer than necessary in the Figure 2 circuitry.)

An amplitude detector 77 denominated the "color burst presence detector" detects when burst is present in the output signal from the burst gate 75 to supply a ONE that conditions the AFPC signal multiplexer 74 to select the output signal from the first AFPC detector 73 as a first error signal, for application to th controlled oscillator 70 as its AFPC signal. Preferably, from the standpoint of immunity to noise, the amplitude detector 77 comprises a synchronous detector stage followed by a threshold detector stage followed by a short-pulse eliminator. Arrangements of the pixel counter 72 can be made for providing a pair of 3.58 MHz square waves in quadrature phase relationship with each other for application to the synchronous detection portions of the detectors 73 and 77. Arrangements of counters to provide square waves in quadrature phase relationship with each other are familiar to television circuit designers, being commonly used in television stereophonic sound decoders. Short-pulse eliminators are known from radar and are commonly constructed using circuitry for ANDing differentially delayed input signal thereto thereby to generate output signal therefrom.

When a television signal is received without attendant color burst, as in a black-and-white television signal, the reference signal for AFPC of the oscillator 70 will have to be the separated horizontal sync puls s supplied to the AFPC circuitry from the TV receiv r front end 20. The color burst presence detector 77 will supply a ZERO when the composite video signal supplied from the TV receiver front end 20 has no attendant color burst, conditioning the AFPC signal multiplexer 74 to select the output signal from a second AFPC detector 78 to controlled oscillator 70 as its AFPC signal. A sync decoder 79 responds with a ONE to the count(s) of the pixel counter 72 theoretically corresponding to the occurrence of the horizontal sync pulse or a prescribed portion thereof, such as an edge thereof. The output signal from the sync decod r 79 is supplied as feedback signal to the s cond AFPC detector 78, which compares that feedback pulse to an input reference signal taken from the horizontal sync pulses suppli d from the horizontal sync separator in the TV receiv r front end 20 and gen r-ates a second rror signal for b ing selectively applied by the AFPC signal multiplexer 74 to controll d oscillator 70 as its AFPC signal. This AFPC arrange-

ment is called "line-locked-clock" by television engineers.

Stability of the oscillations of the controlled oscillator 70 is required over the number of fields from which the 19th scan lines are taken for accumulation in the temporary line store 60, in order that the accumulation procedure by which the Bessel chirp is separated from those lines adequately suppresses horizontal sync pulse, front porch, back porch including color burst and +30 IRE pedestal. Crystal control of the frequency of the oscillations is a practical necessity; and the automatic phase control (APC) aspect of the AFPC should predominate, with the automatic frequency control (APC) aspect of the AFPC having a very long time constant -- i.e. several fields long.

The circuits for resetting the counters 56, 57 and 72 are omitted from Figure 2 to avoid undue complexity. The scan line counter 56 can be simply reset by the leading edges of vertical sync pulses supplied from the vertical sync separator in the TV receiver front end 20.

The pixel count from the pixel counter 72 is reset when necessary in order to re-synchronize it with the scan lines in the composite video signal supplied from the video detector of the TV receiver front end 20. The leading and trailing edges of the horizontal sync pulses supplied from the horizontal sync separator of the TV receiver front end 20 are detected, using a differentiator followed by appropriate level comparators. The leading edge detector result is used to command the loading of a temporary storage register with the current pixel count. The pixel count is applied to a window comparator to determine if it is within its expected range and to generate an indication of error if it is not. The count of the pixel counter 72 is conditionally reset to zero responsive to the trailing edge detector result. The condition for reset may be a single indication of pixel count error. However, better noise immunity is obtained by counting the errors in an up-/down counter configured so a given number of consecutive errors must be counted before pixel count is corrected.

Figure 3 shows circuitry for resetting the modulo-eight field counter 57 so its count either is correctly phased or is misphased by four fields. The temporary line store 31 is shown as being a random-access memory addressed by the pixel count supplied from the pixel counter 72. The line store 31 is arranged for read-then- write operation. The logic ONE issued by the decoder 58 only during the 19th scan line of each fi ld is furnished to a multiplexer 310 to condition the updating of the t mporary line store 31 with digitized 19th scan line samples suppli d from the ADC 50. During other scan lines the logic ZERO issued by th decoder 58 conditions the multiplex r 310 to apply the data read from the temporary line store 31 for writing back thereinto.

Th temporary lin store 31 is provided with pix l

latches 32 and 33 clocked by the output signal from the zero-crossing detector 71. The pixel latches 32 and 33 are us d for temporarily storing th last pixel written into the temporary line store 31 and the last pixel read out of the temporary line store 31, respectively, aligning those samples in time to be respective ones of the subtrahend and minuend input signals of a digital subtractor 34. The pixel samples of the difference signal from the subtractor 34 will all be zero valued except during 19th scan lines. The difference signal from the subtractor 34 is furnished to an absolute-value circuit 35, which can comprise a battery of two-input exclusive-OR gates each receiving the sign bit of the difference signal as a first input and receiving a respective other bit of the difference signal for selectively complementing, and which can then further comprise a digital adder for adding the sign bit of the difference signal to the selectively complemented remaining bits of the difference signal to generate as a sum output signal the absolute value of the difference signal.

An accumulator 36 for successive samples of the absolute- value circuit 35 output signal includes an output latch 361 for temporarily storing successive values of the accumulation result. a digital adder 362 for adding the successive samples of the output signal of the absolute-value circuit 35 to the accumulation result to augment its value, and a multiplexer 363 for selectively supplying the augmented accumulation result to the output latch 361 for updating its contents. The multiplexer 363 is wired for inserting arithmetic zero into the output latch 361 whenever the decoder 58 does not detect the counter 56 supplying a scan line count of nineteen. A decoder 364 responds to the pixel count from the counter 72 being descriptive of those portions of a scan line as may contain Bessel chirp information to furnish a ONE, which is ANDed with the output signal from the zero-crossing detector 71 in an AND gate 365. The output latch 361 is clocked to receive input data responsive only to a ONE being received from the AND gate 365.

The successive samples of the absolute value of the difference of the nineteen lines of the current and previous fields, as supplied serially from the absolute-value circuit 35, are accumulated using the accumulator 36. The accumulation result should have appreciable value if the current field is not FIELD 001 or FIELD 101. The 19th lines of FIELD 000 and of FIELD 001 both contain ETP signal, so their difference is zero-valued except for noise. The 19th lines of FIELD 100 and of FIELD 101 both contain ETR signal, so their difference is zero-valued except for nois . The output signal of a threshold detector 37, which is a ONE when the accumulation result is substantially mor than arithmetic z ro and is otherwise a ZERO, is complemented by a NOT gate 38 to supply one of the four input signals of an AND gat 39. A decoder 41 detects the field count from the counter 57

being other than 001 or 101 to furnish a ONE to the AND gate, which ONE is indicative that the field count is misphased and enables the res tting of the count r 57. The output signal of the decoder 58, which detects the occurrence of the 19th line of a field, and the output signal of a decoder 42, which responds to the pixel count from the counter 72 to detect the end of a scan line, are the other two input signals to the AND gate 39. Providing that the field count is not 001 r 101, the AND gate 39 generates a ONE to reset the counter 57 to 001 field count at the end of the 19th line of a FIELD 000 or of a FIELD 100 in the television signal received by the TV receiver front end 20. Alternatively, the counter 57 could be reset to 101; or provision can be made for resetting only the two least significant bits of the field count, resetting them to 01.

Returning to Figure 3, if the modulo-eight field count provided by the field counter 57 is correctly phased, the accumulation result attained in the temporary line store 60 during FIELD 000, the last field in the cycle of accumulation, will be eight times the ETP Bessel chirp signal devoid of accompanying horizontal sync pulse, front porch, back porch including color burst and +30 IRE pedestal. On the other hand, if the modulo-eight field count provided by the fi ld counter 57 is misphased by four fields, the accumulation result attained in the temporary line store 60 during FIELD 000, the last field in the cycle of accumulation will be eight times the ETR Bessel chirp signal devoid of accompanying horizontal sync pulse, front porch, back porch including color burst and +30 IRE pedestal. A wired three binary place shift in the direction towards reduced magnitude divides the accumulation results attained in the temporary lin store 60 during FIELD 000 by eight, and the resulting quotients are supplied as the ETP or ETR signal to the filter- coefficient computer 55.

The filter-coefficient computer 55, which is w ll-adapted to performing correlations against a ghost-free Bessel chirp function ETP or ETR stored in an internal register thereof, is programmed to perform a correlation substep that determines whether the input it receives from the temporary line store 60 during FIELD 000 is ETP signal, is ETR signal, or is unrelat d to the ETP or ETR signal. This procedure enables the filter-coefficient computer 55 to determine when no GCR signals are included in the television signal received by the TV receiver front end 20. The computer 55 may then apply predetermined "bypass mode" weighting coefficients as stored in registers therewithin to the filters 51, 52 and 53. Alt rnatively, the computer 55 may be arranged to compute weighting coefficients for the filters 51, 52 and 53 proceeding from data conc rning r ceived ghosts supplied by means that do not rely on GCR signals being included in the television signal receiv d by the TV receiver front end 20.

In other variations of the Figure 3 circuitry, circuitry external to the computer 55 is provided for analyzing the GCR signal stored in the temporary line store 31 (during the scan line following its acquisition, for example) to determine whether it is an ETP or ETR signal and this determination is used to determine whether the most significant bit of the reset condition for the field counter 57 is a ZERO so that reset is to 001 field count, or is a ONE so that reset is to 101 field count. The contents of the temporary line store 31 are scanned in accordance with the pixel count from the counter 72 during the analysis procedure.

In an exemplary analysis procedure, the portions of the pixel count corresponding to the initial lobe of the Bessel chirp are decoded to selectively generate a ONE that is used to enable accumulation by either of two accumulators. One accumulator further requires that the sign bit of the current GCR signal be ZERO in order to accumulate its magnitude (absolute-value) in excess of a threshold value T. The other accumulator further requires that the sign bit of the current GCR signal be ONE in order to accumulate its magnitude (absolute-value) in excess of a threshold value T. After the portion of the pixel count corresponding to the initial lobe of the Bessel chirp is scanned, the magnitudes of the accumulator contents are each compared in respective comparators to a threshold value T that is almost as large as the integral of the absolute value of the initial lobe of the Bessel chirp. If the contents of the accumulator that requires that the sign bit of the current GCR signal be ZERO in order to accumulate exceeds this threshold T after the initial lobe of the Bessel chirp, the comparator associated with that accumulator furnishes a ONE to the filter-coefficient computer 55, which ONE together with a ZERO from the other comparator identifies the presence of an ETP signal. Conversely, if the contents of the accumulator that requires that the sign bit of the current GCR signal be ONE in order to accumulate exceeds this threshold T after the initial lobe of the Bessel chirp, the associated comparator furnishes a ONE to the computer 55, which ONE together with a ZERO from the other comparator identifies the presence of an ETR signal. If this threshold T is not exceeded by the contents of either of these accumulators after the initial lobe of the Bessel chirp, the two associated comparators both furnish ZEROs to the computer 55, which determines that neither an ETP or an ETR signal exists in the television signal which the Figure 2 apparatus is attempting to deghost. In further refinements of this schem , the threshold value T is adjusted responsive to noise and GCR signal amplitud conditions.

Variations of the Figure 2 ghost-suppression circuitry are possible wher in, wh n data is being transferred from the temporary line store 60 to a line storage register in th filter-coefficient computer 55, th addressing of the temporary line store 60 and of the line storage register being transferred to is generated within the computer 55, instead of by the pixel counter 72. A multiplex_r under control of decoder 58 or of the computer 55 can apply addresses to the temporary line store 60, selecting them from the pixel counter 72 during the 19th line of each field and otherwise selecting them from those provided by the computer 55. Variations of the Figure 2 ghost-suppression circuitry are also possible wherein a plurality of temporary lin stores are used, instead of a single temporary lin store 60, enabling the computer 55 to update the coefficients of the filters 51, 52 and 53 more often than on an eight-field cycle.

Another modification that can be made to th Figure 2 ghost-suppression circuitry is the accumulation in the temporary line store 60 of the 19th scan lines from sixteen consecutive fields, rather than eight. This further correlates the separated Bessel chirp information, which significantly improves its signal-to-noise ratio as supplied to the filter-coefficient computer 55. In such variations of the Figure 2 ghost-suppression circuitry the modulo-8 field counter 57 is replaced by a modulo-16 field counter and the decoder 65 is replaced by a decoder that generates a ONE when and only when FIELD COUNT from that modulo-16 field counter is 0000. The temporary 1-line store 60 will then accumulate GCR signals from sixteen consecutive fields, which can be divided by sixteen using a wired 4-binary-place shift to supply the computer 55 an updated reduced-noise GCR signal with attendant ghosts. Further accumulation -- e.g. of the 19th scan lines from 24 consecutive fields -- provides little more improvement in the signal-to-noise ratio of the separated Bessel chirp information supplied to the filter-coefficient computer 55.

In further or still other variations of the Figure 2 ghost- suppression circuitry the temporary single-scan-line store 60 is replaced by a temporary two-scan-line store and the decoder 58 is replaced by a decoder for detecting the presence of the 18th or 19th scan lines to supply ONEs for two consecutive scan lines to condition the multiplexer 59 for loading the temporary two-scan- line store. The decoder 64 is replaced by a decoder for detecting the presence of the 261st or 262nd scan lines to supply ONEs for two consecutive scan lines to the AND gate 63. The AND gate 63 responds to the ONEs during the 261st or 262nd scan lines of each field identified by a FIELD COUNT with all bits ZEROs to condition the multiplexer 62 to empty the contents from the temporary two- scan-line store. Or th temporary single-scan-line stor 60 may be replaced by a temporary three-scan-line store and the d coder 58 may be replaced by a decoder for detecting the presence of the 18th through 20th scan lines to condition the multiplexer 59 for loading th temporary three-scan-line store, with suitable provisions for periodically erasing the 3-line store. These arrangements facilitate the pairwise

combination of VBI intervals containing antiphase GCR signals and in-phase other referenc signals, in order to suppress long r-delayed macroghosts.

From the standpoint of simplifying hardware, the decoder 64 of Figure 2 is preferably replaced by any one of several simpler decoders each of which provides a ONE for one line or a pair of lines after the 19th line, but before the 262nd line. For example, a decoder that detects a ONE in the eighth least significant bit of LINE COUNT may be used together with the decoder 65 to supply the two input signals of the AND gate 63. The AND gate 63 will then condition the multiplexer 62 to empty the contents of the temporary line store 60 on each of the scan lines after the 255th in the field identified by the FIELD COUNT that is zero in every binary place.

Figure 4 shows the flow diagram of one method for establishing the operating parameters of the filters 51, 52 and 53, which procedure is carried out by the filter-coefficient computer 55. This method uses successive-approximation techniques to correct for interaction between the responses of the filters 51 and 52 when both leading and trailing macroghosts accompany the predominant image. Entry to the START condition 81 of the Figure 4 procedure is at the time power is turned on in the television receiver, when a new channel is tuned, or when a prescribed time has elapsed since the last deghosting procedure. A RESET ALL DEGHOST FILTERS step 82 preferably sets the filter coefficients in the filters 51, 52 and 53 to values previously determined for the channel to which the TV receiver front end 20 is tuned and stored in a channel-addressed memory. Alternatively, during power-up or returning, the filter coefficients in the filters 51, 52 and 53 can be set to "bypass mode" values associated with a ghost-free signal; and during periodic deghosting previous values of the filter coefficients are retained during "reset".

An ACQUIRE DATA step 83 then follows, which step 83 is completed after the number of fields elapse that the computer 55 must wait for accumulation in the temporary line store 60 to be completed, in order to generate a separated GCR signal that is suitable input data for the computer 55. The ACQUIRE DATA step 83 includes a correlation substep not shown in Figure 4 which substep determines whether the input the computer 55 receives from the temporary line store 60 during FIELD 000 is ETP signal, ETR signal, or is unrelated to the ETP or ETR signal.

A CHANNEL CHARACTERIZATION step 84 then takes place. The computer 55 carries this out by correlating, in the time domain, the ghost-free GCR signal stored in its permanent memory with the ghosted GCR signal separated from the received composite video signal. The location in time of the predominant response in the data supplied the computer 55 is detected, then the respective location in time of each successively smaller one of the significantly large

ghost responses, up to the number of post-ghosts that can be suppr ssed by the filter 51 and up to the numb r of preghosts that can be suppr ssed by the filter 52. The respective locations in time of the predominant response and multipath responses in the data supplied the computer 55 are calculated and stored temporarily in the internal memory of the computer 55, to be used as the basis for programming the bulk delay lines interspersed between the clumps of taps in the IIR filter 51. The relative strengths of th predominant response and multipath responses in the data supplied to the computer 55 are calculated by the computer 55 and stored temporarily in its internal memory, to be used as the basis for assigning weights to the clumped taps of IIR filter 51 and to the taps of FIR filter 52.

Figure 7 shows a set of substeps that the filt r coefficients computer 55 can be programmed to do in order to perform the CHANNEL CHARACTERIZATION step 84. Just after a START STEP condition 840, in an initial substep 841, the discrete Fouri r transform (DFT) of the acquired GCR signal is calculated. Then, in a substep 842 the computer 55 divides the terms of that DFT by the corresponding terms of the DFT of a ghost-free GCR signal, which latter DFT is known a priori and is stored in the internal memory of the computer 55. This term-by-term division procedure of the substep 842 generates the DFT of the reception channel, which is temporarily stored in the internal memory of the computer 55.

As part of the CHANNEL CHARACTERIZATION step 84, it is preferable to normalize the terms of the DFT of the reception channel respective to the energy in the predominant image. In a substep 843 the computer 55 responds to its programming to sort out the largest-magnitude term of the DFT of the reception channel. Then, in a subsequent substep 844 the r-m-s energy of that term and its closeby surrounding terms (e.g. twelve on each side) is determined and temporarily stored in the internal memory of the computer 55. Normalization could be done on the predominate image and all ghost images, but it is preferably from the standpoint of reducing calculations to perform normalization only on those terms descriptive of "strong" ghosts, or ghosts with appreciable energy, and to replace the other terms with zeroes.

The determination of terms descriptive of strong ghosts in a substep 845 is done as follows. The r-m-s energy of the largest- magnitude term of the DFT of the reception channel and its closeby terms, which terms describe the predominant image, is scaled down to provide a threshold level against which to compare the other terms of the DFT of the reception channel. A threshold level -30 dB down from the r-m-s energy of the predominant image has been found satisfactory. Each of the terms of the DFT of the reception channel that exceeds that threshold l vel is considered to be d scriptive of a str ng ghost image

and is compared to its n ighbouring terms to determine the largest local term and locate in tim the centr of the strong ghost. The larg st local term and its closeby terms, as are descriptive of the strong ghost image, are tagged in the internal memory of the computer 55. The storage of the terms of a DFT in the computer 55 can be done in respective storage locations as addressed by time bin, and tagging is then done by setting to prescribed value a tag bit associated with the bits describing the magnitude of the term.

Then, in a substep 846 that discards weak ghost images in the reception channel DFT to generate an approximated DFT of the reception channel, the computer 55 changes to zeroes the values of all the non-tagged terms of the reception channel DFT temporarily stored in its internal memory.

In a normalization substep 847, the computer 55 divides each of the tagged terms in the approximated DFT by the r-m-s energy of the predominant image, to generate a normalized approximated DFT of the reception channel. This normalized approximated DFT of the reception channel is temporarily stored in the internal memory of the computer 55, to be used to support the remaining portions of the calculations, before a STEP DONE condition 848 is finally reached in the step 84. The tags are retained on the terms of the normalized approximated DFT of the reception channel temporarily stored in the internal memory of the computer 55, so the tags can be used for implementing a later decision step 88 in the Figure 4 procedure.

A STABLE GHOST? decision step 85 follows the CHANNEL CHARACTERIZATION step 84. This step is carried forward in the computer 55 using a subroutine where the results of the CHANNEL CHARACTERIZATION step 84 just previous to the most recent CHANNEL CHARACTERIZATION step 84 are fetched from a register in the internal memory of the computer 55 and are replaced in that register by the results of the current CHANNEL CHARACTERIZATION step 84. The computer 55 cross-correlates the results of the most recent CHANNEL CHARACTERIZATION step 84 with the results of the just-previous CHANNEL CHARACTERIZATION step 84 to determine whether the correlation is sufficiently good that the ghosting conditions can be considered stable, or unchanging. Only if the ghosting conditions are substantially unchanging is a Y(ES) signal generated indicating a basis for going on further with the deghosting procedure using the most recent CHANNEL CHARACTERIZATION r sults. If the A STABLE GHOST? decision step 85 g nerates an N(O) signal indicative of changing ghost conditions, op ration in the computer 55 loops back to the ACQUIRE DATA step 83, and th adjustabl filtering parameters of th IIR filter 51 and of th FIR filter 52 ar left unchanged. If the STABLE GHOST? decision step 85 generates

a Y(ES) signal, the procedur go s on to steps 86-88, which use th most recent CHANNEL CHARACTERIZATION step 84 results as the basis for updating the adjustable filtering parameters of the IIR filter 51 and of the FIR filter 52.

In the UPDATE IIR COEFFICIENTS step 86 the programmable delays and the non-zero weighting coeffients of the IIR filter 51 are updated by the computer 55, using the most recent CHANNEL CHARACTERIZATION step 84 results as the basis for the updating. More particularly, for the post-ghost portion of the most recent normalized approximated reception channel DFT, those tagged terms later in time than the largest-magnitude term, are complemented to generate the DFT of the desired IIR filter 51 response, from which DFT the updated IIR filter coefficients are taken. The non-zero terms of the DFT of the desired IIR filter 51 response are used to determine weighting coefficients. If the IIR filter 51 is of a sparse coefficient type, the computer 55 operates to measure the lengths of intervals containing just untagged zero coefficients, to determine the values of delay for the adjustable bulk delay devices. The computer 55 applies the updated IIR filter parameters to the IIR filter 51.

An UPDATE FIR COEFFICIENTS step 87 is performed by the computer 55 after it performs the UPDATE IIR COEFFICIENTS step 86. The non-zero weighting coeffients of the FIR filter 52 are updated by the computer 55, using the most recent CHANNEL CHARACTERIZATION step 84 results as the basis for the updating. More particularly, for the preghost portion of the most recent normalized reception channel DFT results, those earlier in time than the largest-magnitude term, are complemented to generate the DFT of the desired FIR filter 52 response, from which DFT the updated FIR filter coefficients are taken. If the FIR filter 52 is of a sparse coefficient type, the computer 55 operates to measure the lengths of intervals containing all zero coefficients, to determine the adjustable delay of bulk delay devices. The computer 55 applies the updated FIR filter coefficients to the FIR filter 52.

Figure 4 shows a decision step 88 of GHOSTS BELOW THRESHOLD? being reached by the computer 55 after the UPDATE IIR COEFFICIENTS and UPDATE FIR COEFFICIENTS steps 86 and 87 are performed. The step 88 may be implemented proceeding from a count of the number of tags attached to terms of the normalized approximated reception channel DFT in th CHANNEL CHARACTERIZATION step 84, the count being fifteen or below (i.e. the count not being appreciably higher than th number of tags associated with the predominate image) generating a Y(ES) signal, and the count being sixte n or above generating a N(O) signal. Alternatively, the step 88 may be impl mented proceeding from a count of the number of untagged terms, inasmuch as

the numb r of tagged terms and the number of untag-
ged terms sum to a prescribed total number of terms.

An N(O) signal resulting from the GHOSTS BE-
LOW THRESHOLD? step 88 directs the operation of
the computer 55 to a MAXIMUM NUMBER OF ITER-
ATIONS STEP 89. An iterations counter in the com-
puter 55 counts the number of consecutive N(O) sig-
nals resulting from the GHOSTS BELOW THRESH-
OLD? decision step 88 and is reset to zero count by
a Y(ES) signal resulting from the GHOSTS BELOW
THRESHOLD? step 88. An N(O) signal resulting from
the GHOSTS BELOW THRESHOLD? step 88 before
maximum count is reached by this iterations counter
loops operation back to the ACQUIRE DATA step 83.
If the decision in step 88 is Y(ES), all significant
ghosts have been cancelled, or, if the decision in step
89 is Y(ES), indicating that sufficient iterations have
been made that there is assurance that the filters 51
and 52 do not have the capability to be further adjust-
ed to cancel at least one more ghost, the part of the
procedure having to do with. cancelling macroghosts
is completed in the computer 55, and the computer 55
proceeds on to an UPDATE EQUALIZATION COEF-
FICIENTS step 90 in which weighting coefficients for
the amplitude-equalization filter 53 are calculated.
The iterations counter is either reset to zero count by
a Y(ES) signal resulting from one of the decision
steps 88 and 89, or rolls over to zero count.

Figure 8 shows a subroutine that the computer 55
can use for performing the UPDATE EQUALIZATION
COEFFICIENTS step 90. Proceeding from a START
STEP 900 condition, the computer 55 in a substep
901 responds to its programming to compute, from
the response of the macroghost cancellation filter
comprising the cascade connection of the filters 51
and 52, the DFT of just the Bessel chirp portion of the
ghosted GCR signal as separated from the rest of
that signal by a windowing procedure. This DFT has
non-zero terms only closeby its largest-magnitude
term and in a substep 902 is divided term by term into
the DFT of the ideal response to a ghost-free win-
dowed Bessel chirp, as drawn from the permanent
memory of the computer 55. This generates the DFT
of the equalization filter 53, which is the basis for the
computer 55 calculating in a substep 903 updated tap
weights of the FIR filter 53, used to counter the ef-
fects of microghosts. The bin width of the DFT terms
can be the same as the bin width of the DFT terms
involved in the calculations of the adjustable filtering
parameters of the filters 51 and 52 used to suppress
macroghosts. The number of taps for the FIR filter 53
is typically n mor than thirty-one, howev r, so the
number of spectral bins in the truncated DFT is rea-
sonably small and the time required to do these cal-
culations is not unreasonably lengthy. The division
procedures in these methods of performing equaliza-
tion are prone to error when the GCR signal is noisy
or when division is by small numbers, so there is

some need for limiting the upward range of quotients.
In a final substep 904, just before a STEP DONE con-
dition 905 is reached, the updated weighting coeffi-
cients calculated by the computer 55 in substep 903
are applied to the coefficient registers of the FIR filt r
53.

Following the computer 55 performing the UP-
DATE EQUALIZATION COEFFICIENTS step 90, an-
other ACQUIRE DATA step 91 follows in the Figure 4
procedure. Step 91 is completed after the number of
fields elapse that the computer 55 must wait for ac-
cumulation in the temporary line store 60 to be com-
pleted, in order to generate a separated GCR signal
that is suitable input data for the computer 55. Th
ACQUIRE DATA step 91 includes a correlation sub-
step not shown in Figure 4 in which substep the com-
puter 55 determines whether the input it receives
from the temporary line store 60 during FIELD 000 is
ETP signal, ETR signal, or is unrelated to the ETP or
ETR signal.

Another CHANNEL CHARACTERIZATION step
92 is then performed by the computer 55, using any
ETP or ETR signal acquired in the step 91 to recalcu-
late the DFT of the reception channel. In a GHOSTS
SAME? decision step 93 the computer 55 determines
whether the DFT of the reception channel recalculat-
ed in the CHANNEL CHARACTERIZATION step 92
correlates with the DFT of the reception channel as
previously calculated in the CHANNEL CHARAC-
TERIZATION step 84. From the standpoint of easy
implementation, the correlation is preferably done in
an indirect manner by checking to see if the residual
ghosts in both the CHANNEL CHARACTERIZATION
step 84 and the CHANNEL CHARACTERIZATION
step 93 are all below prescribed threshold level. If the
correlation is good. indicating that ghosting has not
changed appreciably, the decision step 93 generates
a Y(ES) signal that loops operation back to the AC-
QUIRE DATA step 91, to continue checking to find out
whether or not ghosting has changed appreciably.
The filtering parameters of the filters 51-53 are left
unchanged by the computer 55.

If the correlation is poor, indicating that ghosting
has changed, the decision step 93 generates a N(O)
signal that loops computer 55 operation back to the
RESET ALL DEGHOST FILTERS step 82. This proce-
dure disables ghost suppression when rapidly chang-
ing multipath conditions occur or when a different re-
ception channel is selected. The filtering parameters
of the filters 51-53 are then subject to recalculation
by the computer 55, following the steps already de-
scribed.

In the Figure 4 procedure the computer 55 per-
forms the UPDATE IIR COEFFICIENTS step 86 and
the UPDATE FIR COEFFICIENTS step 87 indepen-
dently of each other during each passage through
these two successive steps. The updating of the filter
coefficients of the initial one of the cascaded ghost-

cancellation filters, here the post-ghost filter 51, giv s rise to "filter-generated" ghosts of the type that could be suppressed by updating of the filter coefficients of the final one of these filters, here the pre-ghost filter 52. Since the UPDATE IIR COEFFICIENTS step 86 and the UPDATE FIR COEFFICIENTS step 87 do not take these "filter-generated" ghosts into account, the subsequent recalculation of th weighting coefficients of the cascaded ghost-cancellation filters 51 and 52 during the next passage through these two successive steps will introduce compensatory ghosts that will reduce the "filter- generated" ghosts in the final filter response. Since this reduction may not be complete, recalculation of the weighting coefficients of the final one of the cascaded ghost-cancellation filters should be provided for. The loop around steps 83–89 implements these recalculations by the computer 55.

Figure 5 shows the flow diagram of an alternative method for establishing the operating parameters of the filters 51, 52 and 53, which procedure is carried out by the filter-coefficient computer 55. This method is similar to the Figure 4 method, but dispenses with the UPDATE EQUALIZATION COEFFICIENTS STEP 90 after the GHOST BELOW THRESHOLD? decision step 88 in favour of an UPDATE EQUALIZATION COEFFICIENTS STEP 94 before the decision step 88. The UPDATE EQUALIZATION COEFFICIENTS STEP 94 is included in the iteration loop in order that the adjustment of the weighting coefficients of the equalization filter may be effected slowly, over many steps of acquiring GCR signal data. This reduces the sensitivity of the weighting coefficients of the equalization filter to noise accompanying the GCR signal. The GCR signal is coherent over many steps of acquiring GCR signal data, to consistently adjust the weighting coefficients of the equalization filter towards desired values. The noise accompanying the GCR signal is incoherent -- i. e. random over many steps of acquiring GCR signal data -- so its effect on the values of the weighting coefficients of the equalization filter averages to zero on a least-means-squares-error basis.

Figure 12 shows the subroutine used by the computer 55 in performing the UPDATE EQUALIZATION COEFFICIENTS step 94. The filter 53 weighting coefficients are adjusted by the computer 55 in the step 94 so that the response of the cascade connection of filters 51-53 accumulated in the temporary line store 60 best fits an ideal response to a ghost-free GCR Bessel chirp, as st red in the memory of the computer 55. Responding to a START STEP condition 904, the computer 55 in a substep 941 responds to its programming to compute. from the response of the macroghost cancellation filter comprising th cascad connection of the filters 51 and 52, the DFT of just the Bessel chirp portion of the ghosted GCR signal as s parated from the rest of that signal by a

windowing procedure, aft r which initial substep 941 the subroutine progress s to a substep 942. In the substep 905, the computer 55 responds to its programming to generate the cross-correlation of the DFT of just the Bessel chirp portion of the ghosted GCR signal to the DFT of the ideal response to a ghost-free windowed Bessel chirp, as drawn from the permanent memory of the computer 55. To generate the cross-correlation result the computer 55 considers the terms of one of the DFTs in reversed-time sequence and successively uses them to to multiply the terms of the other DFT. (Refer to pages 69-71 and 471 of DIGITAL SIGNAL PROCESSING IN VLSI by Richard J. Higgins, Prentice Hall, Englewood Cliffs NJ.) The cross-correlation is carried out on a circular basis, with the DFTs each wrapping around on itself in the time domain. The result of this correlation procedure determines the timing reference to which the central tap of the equalization filter 53 will be referred and respective to which the relative delays afforded at the other taps of the filter 53 will be referred.

In a subsequent substep 943, The computer 55 calculates the changes in the "middle" terms of the cross-correlation response required to bring them into correspondence with the result of cross- correlating an infinite-bandwidth windowed ghost-free Bessel chirp with the ideal response to a windowed ghost-free Bessel chirp. The ideal response to a windowed ghost-free Bessel chirp used in this and the Figure 8 subroutine could have a $(\sin x)/x$ envelope in the time domain, descriptive of a low-pass step response in the frequency domain. However, usually a subjectively more pleasing video image is one which has some high-frequency peaking to improve transient response; so the ideal response to a ghost-free GCR Bessel chirp stored in the memory of the computer 55 for use in equalization may preferably be one having appropriate high- frequency peaking.

In a subsequent substep 944 leading to the STEP DONE condition 945, the computer 55 increments (or decrements) each of the weights in the equalization filter by a fraction of the change required to bring it into correspondence with the result of cross- correlating an infinite-bandwidth windowed ghost-free Bessel chirp with the ideal response to a windowed ghost-free Bessel chirp. This procedure, together with the iteration loop around steps 88, 89, 83-87 and 94 in the procedure carried out by the computer 55, slowly adjusts the weighting coefficients of the equalization filter 53. This makes it less likely that impulse noise accompanying the GCR signal will l ad to erroneous calculation of the qualization filter 53 weighting coefficients.

Figure 6 shows th flow diagram of another alternativ method the filter-coeffici nt computer 55 can use for establishing the operating parameters of the filters 51, 52 and 53. In the Figure 6 method th computer 55 calculates, without need for successiv ap-

proximation, the corrections for the interaction be-
tw en the responses of the filters 51 and 52 when
both leading and trailing macroghosts accompany
the predominant image. Entry to the START condi-
tion 81 of the Figure 6 procedure is the same as for
the Figure 4 procedure; and the RESET ALL DE-
GHOST FILTERS step 82, the ACQUIRE DATA step
83, the CHANNEL CHARACTERIZATION step 84,
the STABLE GHOST? decision step 85, and the loop
back from step 85 to step 83 are the same in both the
Figure 4 and Figure 6 procedures.

When a Y(es) output signal is generated by the
STABLE GHOST? decision step 85, the Figure 6 pro-
cedure progresses to a CALCULATE IIR COEFFI-
CIENTS step 96 and a CALCULATE FIR COEFFI-
CIENTS step 97. The calculations of the adjustable
filtering parameters for the filters 51 and 52 carried
out by the computer 55 in the steps 96 and 97 of the
Figure 6 procedure, which steps can be performed in
any order, correspond to the calculations carried out
in the UPDATE IIR COEFFICIENTS step 86 and the
UPDATE FIR COEFFICIENTS step 87 of the Figure
4 procedure. However, in the Figure 6 procedure the
computer 55 defers application of the adjustable fil-
tering parameters to the filters 51 and 52 until after
it completes making corrections to these filtering
parameters. A CALCULATE CORRECTIONS FOR
"FILTER-GENERATED" GHOSTS step 98, which will
be described in greater detail further on, follows
steps 96 and 97 of the Figure 6 procedure, in which
step 98 the computer 55 generates adjustments to be
made to the filtering parameters of the filters 51 and
52 as previously calculated in the steps 86 and 87.
Then, in an UPDATE ALL DEGHOST FILTERS step
99 the computer 55 applies the adjusted filtering
parameters to the filters 51 and 52. In the Figure 6
procedure the computer 55 then continues to the UP-
DATE EQUALIZATION COEFFICIENTS step 90. This
continuation is invariably made, there never being
any need for the computer 55 to loop its operation
back to the ACQUIRE DATA step 83 as it does in the
Figure 4 procedure.

The UPDATE EQUALIZATION COEFFICIENTS
step 90, the ACQUIRE DATA step 91, the FURTHER
CHANNEL CHARACTERIZATION step 92, the
GHOSTS SAME? decision step 93, the loop back
from step 93 to step 91 and the loop back from step
93 to step 82 are the same in both the Figure 4 and
Figure 6 procedures.

In the Figure 4 and Figure 6 procedures, the
equalization filter 53 corrects for microghosts gener-
ated during the correction of macroghosts, in addition
to providing corrections for rec iv d microghosts ac-
companying th composit video signal supplied
from the video det ctor, as described above. These
microghosts occur because the cancellation f mac-
roghosts is not carried out on the video signal consid-
ered as a complex signal, but is (in accordance with

the foregoing description) only carried out on the vid-
eo signal considered as a real signal, and because
the number of taps in each clump d-tap segment of
a sparsely tapped ghost-cancellation filter is limited
to only ten or so. The use of the equalization filter 53
to correct for microghosts generated during the can-
cellation of macroghosts is a concept having applica-
tion to configurations where the cancellation of mac-
roghosts is carried out in filter arrangements oth r
than the cascade connection of an IIR filter 51 and an
FIR filter 52, the inventors observe.

The Figure 6 method described above can be
adapted for use where the suppression of macro-
ghosts in composite video signals supplied from the
video detector of a TV receiver or video tape recorder
is carried out using just an IIR filter. In such adapta-
tion the step 99 follows directly after the step 96, and
the steps 97 and 98 are omitted. There will be no ca-
pability for suppressing pre- ghosts, but preghosting
conditions that are serious compared to post- ghost-
ing conditions are relatively rare, usually occurring in
crowded urban environments during off-the-air re-
ception using an omni-directional antenna or a mis-
oriented directional antenna.

The Figure 6 method described above can also
be adapted for use where the suppression of macro-
ghosts in composite video signals supplied from the
video detector of a TV receiver or video tape recorder
is carried out using just an FIR filter. In such adapta-
tion the step 96 is omitted, the step 99 follows directly
after the step 97, and the step 98 is omitted. The sup-
pression of macroghosts using just an FIR filter
avoids the problem of ghost-cancellation continuing
ad infinitum at constantly reduced levels, which can
sometimes cause faintly visible de-ghosting arti-
facts. Group delay problems inherent in IIR filter de-
signs can be avoided.

Figure 9 shows one form in which the sparsely
weighted IIR filter 51 can be implemented. In this Fig-
ure 9 form, the IIR filter 51 is an output-weighted filter
with weights being applied to differentially delayed
signals. The input signal to the IIR filter 51 is applied
as one of the input signals of a multiple-input digital
adder 510 that generates the output signal of the IIR
filter 51. The output signal of the IIR filter 51 is applied
to a delay line having as its initial cascaded compo-
nents a bulk delay device 511, an FIR filter section
512, a bulk delay device 513, an FIR filter section
514, a bulk delay device 515, an FIR filter section
516, a bulk delay device 517, and an FIR filter section
518. The output signals from the respective sum-and-
weight portions of the output-weighted FIR filter sec-
tions 512, 514, 516 and 518 are linearly combined
with each other (and output signals from any other
FIR filter sections cascaded after them) and with the
filter 51 input signal by the adder 510, to generate the
output signal of the IIR filter 51. Each of the FIR filter
sections 512, 514, 516 and 518 can cancel a respec-

tive post-ghost from that output signal.

Figure 10 shows one form in which the spars ly w ighted FIR filter 52 can be implemented. In this Figure 10 form, the FIR filter 52 is an output-weighted filter with weights being applied to differentially delayed signals. The input signal to the FIR filter 52 is applied to a delay line having as its final cascaded components a bulk delay device 529, an FIR filter section 528, a bulk delay device 527. an FIR filter section 526, a bulk delay device 525, an FIR filter section 524. a bulk delay device 523, an FIR filter section 522 and a bulk delay device 521. The output signals from the respective sum-and-weight portions of the output-weighted FIR filter sections 522, 524, 526 and 528 are linearly combined with each other (and output signals from any other FIR filter sections cascaded before them) and with the output signal from the a bulk delay device 523. using a multiple-input digital adder 520, thereby to generate the output signal of the FIR filter 52. Each of the FIR filter sections 522, 524, 526 and 528 can cancel a respective pre- ghost from that output signal.

The respective delay of each of the bulk delay devices 511 513, 515, 517, 521, 523, 525, 527 and 529 is programmable in response to a digital signal received in a temporary storage register thereof. The FIR filter sections 522, 524, 526 and 528 are each a multiply-tapped delay line having a sum-and-weight network for applying output weights to its tap signals, each of which weights is programmable in response to a digital signal received in a respective temporary storage register of that FIR filter section.

One skilled in the art of digital filter design can readily convert the output-weighted designs of Figures 9 and 10 to input- weighted forms using known design procedures, but output-weighted forms are often preferred, for filters with adjustable parameters because filtering functions can be adjusted immediately without having to clear out old samples. In a sparsely weighted filter, changes in bulk delays will require having to wait to clear out old samples in order not to introduce artifacts into the image, and these changes are best made during a vertical retrace blanking interval. Alteration of filter response by adjusting tap weights can be done almost instantly, but are better made during a horizontal retrace blanking interval. The Figure 4 procedure may be modified so the computer 55 performs the UPDATE IIR COEFFICIENTS step 86 after the UPDATE FIR COEFFICIENTS step 87, rather than before. The Figure 6 procedure may be modified so the computer 55 performs the CALCULATE IIR COEFFICIENTS step 96 after the CALCULATE FIR COEFFICIENTS step 97, rather than before.

Referring to the Figure 11 flow chart, the procedures involved in the steps 96 and 97 of the Figure 6 procedure will now be considered in greater detail. The details of the st ps 96 and 97 of the Figure 6 pro-

c dure are also pertinent to a mor complete understanding of the steps 86 and 87 of the Figure 4. In this more detailed description the filters 51 and 52 will be referred to as if they have the exemplary structures of Figures 9 and 10, respectively.

The initial DETERMINE MIDDLE TERM OF PREDOMINANT IMAGE step 95 in the Figure 9 flow chart is begun by the computer 55 when a Y(es) output signal is generated by the STABLE GHOST? decision step 85. In step 95 the group of very largest energy terms of the normalized approximated reception channel DFT generated in the CHANNEL CHARACTERIZATION step 84, which group of terms describes the predominant image, is determined and used to establish a time base the computer 55 subsequently uses in calculating the filtering parameters of the IIR filter 51 and FIR filter 52 used for cancelling ghosts. The determination of which group of the terms has the most energy is performed in the CHANNEL CHARACTERIZATION step 84 and the results of that determination can be carried over in the internal memory of the computer 55 for use in the steps 96 and 97 — or, alternatively, the computer 55 may be programmed to repeat that determination at the outset of the series of steps 96 and 97. The terms of the normalized approximated reception channel DFT that are later in time than the group of the terms that has the most energy are considered to be in the post-ghost region and are thus to be used as the basis for calculating the adjustable filtering parameters of the IIR filter 51. The terms of the normalized approximated reception channel DFT that are earlier in time than the group of the terms that has the most energy are considered to be in the preghost region and are thus to be used as the basis for calculating the adjustable filtering parameters of the FIR filter 52. The boundary between the post- ghost region and the preghost region is more sharply defined within the group of the terms having the most energy, the computer 55 being programmed for selecting the largest of these terms (or a "preferred" one of them where there is a plurality of largest terms) as the middle term of the temporal spectrum of the predominant image.

Supposing the CALCULATE IIR COEFFICIENTS step 96 to precede the CALCULATE FIR COEFFICIENTS step 97 in the Figure 6 procedure, steps 961 and 962, which are substeps of the step 96 are performed by the computer 55 after step 95. Then, steps 971 and 972, which are substeps of the step 97 are performed by the computer 55.

In the DETERMINE BULK DELAYS FOR POST-GHOST Cancellation step 961, delays provided by the bulk delay devices in the sparsely weighted IIR filter 51 are calculated by the computer 55. In th CHANNEL CHARACTERIZATION step 84, the largest local terms and their closeby terms, as are descriptive of the predominant imag and strong ghost images, were tagged in the internal memory of th

computer 55. The number of terms in the approximated DFT for the r ception channel that are later in time than the very largest term, and which ith r describe the predominant image or are in the next later run of untagged zero-value terms, are counted by the computer 55, which temporarily stores the resulting count in its internal memory and uses the count to program the delay of the bulk delay device 511. The number of terms in each of the runs of untagged zero-value terms successively later in time are counted by the computer 55, which temporarily stores the respective successive counts in its internal memory and uses the counts to program delays in the bulk delay devices 513, 515, 517... , respectively. Step 961 generates the indexing information for placing the FIR filter sections 512, 514, 516 and 518 at proper delay intervals for the subsequent step 962.

In the DETERMINE TAP WEIGHTS FOR POST-GHOST Cancellation step 962. the computer 55 considers each successively later group of tagged terms in turn and calculates the tap weights for the weight-and-sum network of the corresponding one of the output- weighted FIR filter sections 512, 514, 516, 518,... The subroutine is similar to either the Figure 8 or Figure 9 subroutine for calculating equalization filter 53 tap weights, except that the DFT of the ghosted Bessel chirp and the DFT of the ghost-free Bessel chirp drawn from the internal memory of the computer 55 both extend over a time interval of an entire scan line or two, and are indexed in time vis-a-vis each other. Indexing is by the sum of the time intervals spanned by the bulk delays preceding the one of the FIR filter sections 512, 514, 516, 518,... for which tap weights are being calculated, the delays through the multiply-tapped delay lines through each previous one of those output-weighted FIR filter sections, and half the delay through the multiply-tapped delay line through the FIR filter section for which tap weights are being calculated.

In the DETERMINE BULK DELAYS FOR PRE-GHOST Cancellation step 971 the number of terms in the approximated DFT for the reception channel that are earlier in time than the very largest term, and which either describe the predominant image or are in the next earlier run of untagged zero-value terms, are counted by the computer 55, which temporarily stores the the resulting count in its internal memory and uses the count to program the delay of the bulk delay device 521. The number of terms in each of the runs of untagged zero-value terms successively earlier in time are counted by the computer 55, which temporarily stores the r spective successive counts in its internal memory and uses the counts to program delays in the bulk delay devices 523, 525, 527... , resp ctively. The d lay of the initial bulk delay (529 in Figure 10) in the FIR filter 52 delay line is calculated by subtracting the delay of all the succeeding elements in that delay line fr m a value of d lay as-

sociated with the earliest preghost that suppression is ever to be afforded to; this keeps constant the delay that is provided to the predominant image, so that changes in preghost cancellation does not introduce any side-to-side shake into that image. Step 971 generates the indexing information for placing the FIR filter sections 522, 524, 526 and 528 at proper delay intervals for the subsequent step 972.

In the DETERMINE TAP WEIGHTS FOR PRE-GHOST Cancellation step 972, the computer 55 considers each successively earlier group of tagged terms in turn and calculates the tap weights for th weight-and-sum network of the corresponding one f the output- weighted FIR filter sections 522, 524, 526, 528,... The subroutine is similar to either the Figure 8 or Figure 9 subroutine for calculating equalization filter 53 tap weights, except that the DFT of the ghosted Bessel chirp and the DFT of the ghost-free Bessel chirp drawn from the internal memory of the computer 55 both extend over a time interval of an entire scan line or two, and are indexed in time vis-a-vis each other. Indexing is by the sum of the time intervals spanned by the bulk delays succeeding the one of the FIR filter sections 522, 524, 526, 528,... for which tap weights are being calculated, the delays through the multiply-tapped delay lines through each succeeding one of those output-weighted FIR filter sections, and half the delay through the multiply-tapped delay line through the FIR filter section for which tap weights are being calculated. After step 971 is completed a STEP DONE condition 950 for the steps 96 and 97 is reached.

Steps 95, 961, 962, 971 and 972 as thus far described, together with applications of the computed filtering parameters to the IIR filter 51 and to the FIR filter 52, are essentially similar to the steps 86 and 87 of the Figure 4 method. In steps 95, 961, 962, 971 and 972 the computer 55 calculates filtering parameters for the IIR filter 51 and for the FIR filter 52 on a separable basis. This generates a correct overall ghost-cancellation response for the cascaded filters 51 and 52 only if there are no macroghosts, if there are only trailing macroghosts and no leading macroghosts, or if there are only leading macroghosts and no trailing macroghosts.

Assume the cascade connection of the IIR filter 51, the FIR filter 52 and the equalization filter is as shown in Figure 2. If there are preghosts as well as post-ghosts, the independent calculation of the IIR filter 51 parameters causes them to be such as to delay the predominant image and combine it d structively with each post-ghost. All post-ghosts are suppressed, without generating repeats. The IIR filter 51 delays each preghost similarly to the predominant image, but each delayed preghost usually does not destructiv ly combin with anything and gives rise to a "filt r-generated" ghost. Each preghost giv s rise to one "filter-generated" ghost for each post-ghost be-

ing cancelled, ignoring repeats. By way of example, suppose that relative to the predominant image there are two preghosts at -10 µS and -3 µS, respectively, and that there are three post-ghosts at 4 µS, 8 µS, and 20 µS, respectively. Each preghost gives rise to three "filter- generated" ghosts delayed therefrom by the amount of the delay of the post-ghost respective to the dominant image, and attenuated according to the magnitude of the post-ghost respective to the dominant image. At the IIR filter 51 output, the origi-nal -10 µS preghost gives rise to "filter-generated" ghosts located in time at -6 µS, -2µS, and +10 µS rel-ative to the predominant image: and the - 3 µS pre-ghost gives rise to "filter-generated" ghosts located in time at +1 µS, +5 µS and +17 µS relative to the pre-dominant image. The magnitude of any one of these "filter-generated" ghosts is the product of the magni-tudes of the preghost and the post-ghost giving rise to that"filter-generated" ghost. This process of "inter-nal" ghost generation repeats with progressively re-duced amplitude. For ideal ghost cancellation, these repeat ghosts must also be cancelled or attenuated below levels subjectively found objectionable.

If the deghosting filter structure is IIR filter 52 fol-lowing the FIR filter 51, then the the post-ghosts give rise to "filter- generated" ghosts at the output of the FIR filter 51. The locations of "filter-generated" ghosts are advanced in time relative to the post-ghosts giving rise to them, the amounts of advance-ment depending upon the amounts of time the pre-ghosts precede the predominant image.

Since the locations and magnitude of initial inter-nally generated ghosts can be easily precomputed, the computer 55 can be programmed to compute coefficients for a ghost-cancellation filter that will "generate" ghosts of "opposite" magnitude at appro-priate locations. Thus when a ghost-cancellation fil-ter gives rise to a "filter-generated" ghost, it gets can-c lled due to the "existing" ghost of opposite polarity at the same location. Simultaneously, repeat gener-ation of the ghosts is also prevented. The CALCU-LATE CORRECTIONS FOR "FILTER-GENERATED" GHOSTS step 98 in the Figure 6 method corrects for the interaction between the responses of the filters 51 and 52 that would otherwise give rise to "filter-generated" ghosts when both leading and trailing macroghosts were to accompany the predominant image. ..

The more detailed flow chart of Figure 13 shows substeps of the Figure 6 step 98, carried out by the computer 55 after the steps 95-972. The START con-dition 980 is entered when the last of the steps 96 and 97 is completed or "done". An initial ARE THERE BOTH PRE- & POST-GHOSTS? decision step 981 is performed by the comput r 55, and a N(O) signal re-sult will dir ct the procedure immediately to a STEP DONE condition 988, which is followed by the UP-DATE ALL DE-GHOST FILTERS step 99 of the Figure

6 main routine.

A Y(ES) signal result will caus the computer 55 to continue the subroutine with a CALCULATE DFT OF CONVOLVED IIR & FIR GHOST-Cancellation FILTER RESPONSES substep 982. In substep 982 the computer 55 is programmed to multiply the mag-nitude of each of the terms of the DFT of the re-sponse of one of the filters 51 and 52 by the magni-tude of each of the terms of the DFT of the response of the other filter, the respective products determin-ing the magnitudes of respective terms in the DFT of the convolved responses -- i.e. the DFT of the cas-cade connection of the filters 51 and 52. In substep 982 the computer 55 is further programmed to line-arly combine the lead of the preghost and the lag of the post-ghost giving rise to each term of the DFT of the convolved responses, thereby to determine th location in time of that term.

A DETERMINE STRONG "FILTER-GENERAT-ED" GHOSTS & RECHARACTERIZE CHANNEL substep 983 is then performed by the computer 55. In a procedure similar to that described previously in regard to substep 845 of the Figure 7 subroutine, it is determined whether or not each "filter generated" ghost has sufficient energy to be of concern. A "filter generated" ghost determined in substep 983 to have sufficient energy to be of concern, which ghost oc-curs during a time interval otherwise occupied by non-tagged zero terms in the channel characteriza-tion results and in the corresponding filter parameter listings, replaces those non-tagged zero terms term by term on a tagged basis to "recharacterize" the channel.

Substeps 984, 985, 986 and 987 which follow th substep 983 are carried out by the computer 55 sub-stantially the same way as substeps 961, 962, 963 and 964, respectively, but proceed from the "rechar-acterized" channel characterization results, rather than the original channel characterization results. With the completion of the substeps 984, 985, 986 and 987, the STEP DONE condition 988 is reached by the computer 55, which is followed by the UPDATE ALL DE-GHOST FILTERS step 99 of the Figure 6 main routine.

Where the GCR signal acquisition is carried out so there is little likelihood of appreciable accompany-ing noise, the UPDATE EQUALIZATION COEFFI-CIENTS step 90 in the Figure 4 method or in the Fig-ure 6 method could be carried out in the following al-ternative way. A subroutine similar to the Figure 12 subroutine used to carry out th UPDATE EQUALI-ZATION COEFFICIENTS step 94 is performed by the computer 55, except that the subst p 944 is modified to increment (or decrement) the tap w ights for the equalization filter 53, not by adjustments that are fractions of calculated changes in the cross-correlation, but rather by adjustments that equal cal-culated changes in th cross-correlation. This one-

shot adjustment procedure does not discriminate against noise accompanying the GCR signal.

Th ghost suppression methods described herein are applicable for GCR signals other than those described, although suitable modifications may be necessary in regard to the circuitry used to acquire GCR signals for application to the filter-coefficients computer 55. In any case, the data concerning the a priori information about the ghost-free GCR signal that is contained in the permanent memory portion of the internal memory of the computer 55 will have to be modified to suit the different GCR signal standard. In construing the scope of the method claims which follow this specification, this applicability of the methods to different GCR signal standards should be taken into consideration.

One skilled in the art of programming microcomputers will, when familiarized with the procedures for suppressing ghosts in television signals taught herein, be enabled to make a large number of variants upon the methods specifically described herein; and this fact should be borne in mind when construing the claims which follow, such that the scope of the broader ones of these claims encloses all such variants as embody the spirit of the invention.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of th steps of any method or process so disclosed.

Claims

1. A method of operating apparatus comprising a

receiver for receiving through a reception channel a video signal with accompanying ghost-cancelling reference (GCR) signal both subject at times to being ghosted; a ghost-suppression filter connected for responding to said video signal, said ghost-suppression filter having adjustable filtering parameters; a computer for calculating the adjustable filtering parameters of said ghost-suppression filter, said computer being provided with a read-only memory for permanently storing data descriptive of ghost-free GCR signal and with further memory for purposes of temporary storage; and a GCR-signal separator for separating from the response of said ghost-suppression filter to said video signal the response of said ghost- suppression filter to said received GCR signal, subject at times to being ghosted, to supply a separated GCR signal; said method avoiding the erroneous adjustment of the filtering parameters of said ghost-suppression filter during non-stable ghosting conditions such as "aircraft flutter" and comprising the steps of:

a.) initializing the adjustable filtering parameters of said ghost- suppression filter;

b.) loading said separated GCR signal into said further memory of said computer, for purposes of temporary storage, which loading is done after step (a.) and can be done after other steps in the method as prescribed hereafter in this claim or any claim depending therefrom;

c.) each time after step (b.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that step (b.) to generate a set of updated channel characterization results;

d.) each time after step (c.) is performed, temporarily storing within the further memory of said computer the set of updated channel characterization results generated by that step (c.);

e.) each time after step (c.) is performed, determining within said computer whether or not ghosting conditions have changed, by comparing each portion of the updated set of channel characterization results with the corresponding portion of the previously temporarily stored set of channel characterization results, ghosting conditions being determined not to have chang d only when corresponding portions of the compared sets of channel characterization results in every comparison differ by less than a first threshold value, the method looping back to step (b.) when ghosting conditions are determined to have changed when corresponding portions of the

compared sets of channel characterization re-
sults in any of said comparisons differ by as
much as or mor   than said first threshold val-
ue; and

f.) each time ghosting conditions are deter-
mined not to have changed when step (e.) is
performed, thereafter performing calcula-
tions within said computer for determining the
adjustable filtering parameters for said ghost-
suppression filter.

2. A method of operating apparatus comprising a
receiver for receiving through a reception chan-
nel a video signal with accompanying ghost-
cancelling reference (GCR) signal both subject at
times to being ghosted; a ghost-suppression fil-
ter connected for responding to said video signal
which ghost-suppression filter comprises in a
cascade connection a first filter of a type having
adjustable filtering parameters that can be ad-
justed for suppressing macroghosts in its output
response and a second filter of a type having ad-
justable filtering parameters that can be adjusted
for suppressing microghosts in its output re-
sponse; a computer for calculating the adjustable
filtering parameters of said second filters, said
computer being provided with a read-only mem-
ory for permanently storing data descriptive of
ghost-free GCR signal and with further memory
for purposes of temporary storage; and a GCR-
signal separator for separating from the re-
sponse of said ghost-suppression filter to said
video signal the response of said ghost-
suppression filter to said received GCR signal,
subject at times to being ghosted, to supply a
separated GCR signal; said method comprising
the steps of:

a.) initializing the adjustable filtering parame-
ters of said first and second filters;

b.) loading said separated GCR signal into
said further memory of said computer, for pur-
poses of temporary storage, which loading is
done after step (a.) and can be done after
other steps in the method as prescribed here-
after in this claim or any claim depending
therefrom;

c.) each time after step (b.) is performed, per-
forming calculations within said computer for
characterizing the reception channel as de-
scribed by the separated GCR signal loaded
into said computer during that step (b.) to gen-
erate a set of updated channel characteriza-
tion results;

d.) ach time after step (c.) is performed, tem-
porarily storing within the further memory of
said computer the set of updated channel
characterization results generated by that
step (c.);

e.) each time after st p (c.) is performed, de-
termining within said computer whether or not
ghosting conditions have changed, by com-
paring each portion of the updated set of
channel characterization results with the cor-
responding portion of the previously tempor-
arily stored set of channel characterization re-
sults, ghosting conditions being determined
not to have changed only when corresponding
portions of the compared sets of channel
characterization results in every comparison
differ by less than a first threshold value, the
method looping back to step (b.) when ghost-
ing conditions are determined to hav
changed when corresponding portions of the
compared sets of channel characterization re-
sults in any of said comparisons differ by as
much as or more than said first threshold val-
ue;

f.) each time ghosting conditions are deter-
mined not to have changed when step (e.) is
performed, thereafter performing calcula-
tions within said computer for determining the
adjustable filtering parameters for said first
filter;

g.) after step (f.) has been performed so that
the adjustable filtering parameters for said
first filter satisfactorily reduce all ghosts in
the updated separated GCR signal. perform-
ing calculations within said computer for de-
termining the adjustable filtering parameters
for said second filter;

h.) after step (g.) has been performed, load-
ing an updated separated GCR signal into
said further memory of said computer, for pur-
poses of temporary storage;

i.) each time after step (h.) is performed, per-
forming calculations within said computer for
characterizing the reception channel as de-
scribed by the separated GCR signal loaded
into said computer during that step (h.) to gen-
erate a set of updated channel characteriza-
tion results;

j.) each time after step (i.) is performed, tem-
porarily storing within the further memory of
said computer the set of updated channel
characterization results generated by that
step (i.); and

k.) each time after step (i.) is performed, de-
termining within said computer whether or not
ghosting conditions have changed, by com-
paring each portion of the updated set of
channel characterization results with the cor-
responding portion of the previously tempor-
arily stored set of channel characterization re-
sults, ghosting conditions being determined
not to have changed only when corresponding
portions of th   compared sets of channel

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characterization results in every comparison differ by less than a s cond threshold value, th method looping back to step (a.) when ghosting conditions are determined to have changed when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or more than said second threshold value.

3. A method as set forth in Claim 2, wherein each of the steps (c.) and (i.) comprises the substeps of:

using said computer to calculate the DFT of said separated GCR signal loaded into said computer in the just previous step; and

then using said computer to divide the terms of the DFT of said separated GCR signal by the corresponding terms of the DFT of said ghost-free GCR signal stored in said permanent memory and read therefrom, thereby to generate the DFT of said reception channel, the terms of the DFT of said reception channel comprising the set of channel characterization results generated by the step.

4. A method as set forth in Claim 2 or 3, wherein step (f.) comprises the substeps of:

fa.) using said computer to determine the largest term of the DFT characterizing the response of said reception channel as read from the further memory of said temporary memory in said computer;

fb.) after substep (fa.), using said computer for dividing all of the terms of the DFT characterizing the response of said reception channel by the largest term, thereby to generate the terms of a normalized DFT characterizing the response of said reception channel;

fc.) after substep (fb), using said computer for replacing by a respective zero each of the terms of the normalized DFT that are smaller than a threshold value, thereby to generate an approximated normalized DFT characterizing the response of said reception channel;

fd.) after substep (fc), using said computer for complementing all of the non-zero terms of said approximated normalized DFT characterizing the response of said reception channel except for its largest, thereby to generate th DFT of said first filter; and

fe.) after substep (fd), using said computer for calculating the adjustable filtering parameters for said first filter from its DFT.

5. A method as set forth in Claim 2, 3 or 4, wherein in the step (g.) the substep of performing calculations within said comput r for determining the

adjustable filtering parameters for said second filter is carried out with the following substeps:

ga.) taking from said further memory terms of a truncation of the DFT of said separated GCR signal most recently computed and temporarily stored;

gb.) using said computer to divide the terms of the truncated DFT of said separated GCR signal portion by the corresponding terms of the DFT of a corresponding portion of said ghost-free GCR signal stored in said permanent memory and read therefrom, thereby to generate a truncated DFT of said reception channel;

gc.) generating with said computer the DFT of said second filter so as to complement th truncated DFT of said reception channel;

gd.) determining with said computer updated values for the adjustable filtering parameters of said second filter in accordance with its DFT; and

ge.) applying the updated adjustable filtering parameters to said second filter.

6. A method as set forth in Claim 2, 3, 4 or 5, wherein in the step (g.) the substep of performing calculations within said computer for determining the adjustable filtering parameters for said second filter is carried out with the following substeps:

ga.) reading from said further memory of said computer, the DFT of said separated GCR signal most recently computed and temporarily stored;

gb) calculating with said computer a first truncated DFT, which is of the convolution of the response of said second filter with said separated GCR signal most recently computed and temporarily stored;

gc.) reading from said permanent memory of said computer, terms of a second truncated DFT, which is of the ghost-free GCR signal as convolved by a desired reception channel response;

gd.) determining with said computer the departures of the terms of said first truncated DFT from the corresponding terms of the second truncated DFT; and

ge.) responding to each said departure for adjusting the corresponding adjustable filtering parameter for said second filter in a direction to reduce that departur .

7. A method of operating apparatus comprising a receiver for receiving through a reception channel a video signal with accompanying ghost-cancelling reference (GCR) signal both subject at times to being ghosted; an IIR filter of a type hav-

ing adjustable filtering parameters that can be adjusted for suppressing in its output response trailing macroghosts or post-ghosts accompanying its input signal; an FIR filter of a type having adjustable filtering parameters that can be adjusted for suppressing in its output response leading macroghosts or preghosts accompanying its input signal;

a ghost-suppression filter connected for responding to said video signal which ghost-suppression filter comprises the cascade connection of said IIR filter and said FIR filter;

a computer for calculating the adjustable filtering parameters of said first and said second digital filters, said computer being provided with a read-only memory for permanently storing data descriptive of ghost-free GCR signal and with further memory for purposes of temporary storage; and

a GCR-signal separator for separating from the response of said ghost-suppression filter to said video signal the response of said ghost-suppression filter to said received GCR signal, subject at times to being ghosted, to supply a separated GCR signal: said method comprising the steps of:

a.) initializing the adjustable filtering parameters of said first and second digital filters:

b.) loading said separated GCR signal into said further memory of said computer, for purposes of temporary storage, which loading is done after step (a.) and can be done after other steps in the method as prescribed hereafter in this claim or any claim depending therefrom;

c.) each time after step (b.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that step (b.) to generate a set of updated channel characterization results;

d.) each time after step (c.) is performed, temporarily storing within the further memory of said computer the set of updated channel characterization results generated by that step (c.);

e.) each time after step (c.) is performed, determining within said computer whether or not ghosting conditions have changed, by comparing each portion of the updated s t of channel characterization results with the corresponding portion of the pr viously temporarily stored set of channel characterization results, ghosting conditions b ing det rmined not to hav changed only when corresponding portions of th compared sets of channel characterization results in every comparison

differ by less than a first threshold value, the method looping back to step (b.) when ghosting conditions ar. determined to hav changed when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or more than said first threshold value;

f.) each time ghosting conditions are determined not to have changed when step (e.) is performed, thereafter performing calculations within said computer for determining th adjustable filtering parameters for said IIR filter and said FIR filter in the cascade connection which said ghost-suppression filter comprises;

g.) after step (f.) has been performed so that the adjustable filtering parameters for said IIR filter and said FIR filter satisfactorily reduce all ghosts in the updated separated GCR signal. proceeding from step (f.) to step (h.);

h.) loading an updated separated GCR signal into said further memory of said computer, for purposes of temporary storage;

i.) each time after step (h.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that step (h.) to generate a set of updated channel characterization results;

j.) each time after step (i.) is performed, temporarily storing within the further memory of said computer the set of updated channel characterization results generated by that step (i.); and

k.) each time after step (i.) is performed, determining within said computer whether or not ghosting conditions have changed, by comparing each portion of the updated set of channel characterization results with the corresponding portion of the previously temporarily stored set of channel characterization results, ghosting conditions being determined not to have changed only when corresponding portions of the compared sets of channel characterization results in every comparison differ by less than a second threshold value, the method looping back to step (a.) when ghosting conditions are determined to hav chang d when corresponding portions of the compared s ts f channel characterization results in any of said comparisons differ by as much as or more than said second threshold valu .

8. A method as set forth in Claim 7 for p rating said apparatus wh n the cascade conn ction of

said IIR filter and said FIR filter in said ghost-suppression filter further includes a further FIR filter for suppressing microghosts, in which method the step (g.) of proceeding from step (f.) to step (h.) comprises the substeps of:

performing calculations within said computer for determining updated adjustable filtering parameters for said further FIR filter; and

applying said updated adjustable filtering parameters to said further FIR filter.

9. A method as set forth in Claim 8, wherein in the step (g.) the substep of performing calculations within said computer for determining the adjustable filtering parameters for said further FIR filter is carried out with the following substeps:

ga.) taking from said further memory terms of a truncation of the DFT of said separated GCR signal most recently computed and temporarily stored;

gb.) using said computer to divide the terms of the truncated DFT of said separated GCR signal portion by the corresponding terms of the DFT of a corresponding portion of said ghost-free GCR signal stored in said permanent memory and read therefrom, thereby to generate a truncated DFT of said reception channel;

gc.) generating with said computer the DFT of said further FIR filter so as to complement the truncated DFT of said reception channel;

gd.) determining with said computer updated values for the adjustable filtering parameters of said further FIR filter in accordance with its DFT; and

ge.) applying to said further FIR filter the updated adjustable filtering parameters for said further FIR filter.

10. A method as set forth in Claim 8, wherein in the step (g.) the substep of performing calculations within said computer for determining the adjustable filtering parameters for said further FIR filter is carried out with the following substeps:

ga.) reading from said further memory of said computer, the DFT of said separated GCR signal most recently computed and temporarily stored;

gb) calculating with said computer a first truncated DFT, which is of the convolution of the response of said second filter with said separated GCR signal most recently computed and temporarily stored;

gc.) reading from said permanent memory of said computer, terms of a second truncated DFT. which is of the ghost-free GCR signal as convolved by a desired reception channel response;

gd.) determining with said computer the departures of the terms of said first truncated DFT from the corresponding terms of the second truncated DFT; and

ge.) responding to each said departure for adjusting the corresponding adjustable filtering parameter for said second filter in a direction to reduce that departure.

11. A method as set forth in Claim 7, 8, 9 or 10, wherein said step (f.) comprises the substeps of:

fa.) on a separable basis, calculating within said computer adjustable filtering parameters for said IIR filter; and

fb.) on a separable basis, calculating within said computer adjustable filtering parameters for said FIR filter.

12. A method as set forth in Claim 11, wherein in said step (f.) said substep of calculating adjustable filtering parameters for said IIR filter is performed before said substep of calculating adjustable filtering parameters for said FIR filter.

13. A method as set forth in Claim 11, wherein in said step (f.) said substep of calculating adjustable filtering parameters for said IIR filter is performed after said substep of calculating adjustable filtering parameters for said FIR filter.

14. A method as set forth in Claim 11, 12 or 13, wherein said step (f.) further comprises the substeps of:

fc.) applying to said IIR filter said adjustable filtering parameters calculated in substep (fa.), before any correction of said adjustable filtering parameters for said IIR filter calculated in said substep;

fd.) applying to said FIR filter said adjustable filtering parameters calculated in substep (fb.), before any correction of said adjustable filtering parameters for said FIR filter calculated in said substep;

fe.) determining whether or not the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value;

ff.) counting the determinations that the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below a prescribed third threshold value, the count being initially zero and being reset to zero whenever there is a determination that the adjustable filtering parameters of said IIR filter and said FIR filter do not require adjustment in the current step (f.) in order to reduce

all ghosts below said first threshold value; and

fg.) looping back to step (b.) responsive to said count being below a prescribed count and the determination that the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below said threshold value.

15. A method as set forth in Claim 11, 12 or 13, wherein said step (f.) further comprises the substeps of:

fc.) calculating with said computer corrections for the adjustable filtering parameters of said IIR filter and said FIR filter;

fd.) making said corrections to the adjustable filtering parameters of said IIR filter and said FIR filter; and

fe.) applying to said IIR filter and said FIR filter the resulting corrected adjustable filtering parameters, whereupon the step (f.) has been performed so that the adjustable filtering parameters for said IIR filter and said FIR filter satisfactorily reduce all ghosts in the updated separated GCR signal.

16. A method as set forth in Claim 8, 9 or 10, wherein step (f.) comprises the substeps of:

fa.) using said computer to determine the largest term of the DFT characterizing the response of said reception channel as read from the further memory of said temporary memory in said computer;

fb.) after substep (fa.), calculating with said computer the adjustable filtering parameters of said IIR filter from the smaller terms of the DFT characterizing the response of said reception channel later in time than the largest term of the DFT characterizing the response of said reception channel, which smaller terms of the DFT characterizing the response of said reception channel later in time than the largest term of the DFT characterizing the response of said reception channel exceed a prescribed threshold value; and

fc.) after substep (fa), calculating with said computer the adjustable filtering parameters of said FIR filter from the smaller terms of the DFT characterizing the response of said reception channel earlier in tim than the largest t rm of the DFT characterizing the response of said reception channel, which smaller terms of the DFT characterizing the respons of said reception channel earlier in time than the largest term of the DFT characterizing the response of said reception channel exceed a prescribed threshold value.

17. A method as set forth in Claim 16, wherein said step (f.) further comprises the substeps of:

fd.) applying to said IIR filter said adjustable filtering parameters calculated in said substep (fb.);

fe.) applying to said FIR filter said adjustable filtering parameters calculated in said substep (fc.); ff.) determining whether or not the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value;

fg.) counting the determinations that the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below a prescribed third threshold value, the count being initially zero and being reset to zero whenever there is a determination that the adjustable filtering parameters of said IIR filter and said FIR filter do not require adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value;

fh.) looping back to step (b.) responsive to said count being below a prescribed count and the determination that the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in substep (ff.) of the current step (f.) in order to reduce all ghosts below said threshold value.

18. A method as set forth in Claim 16, wherein said step (f.) further comprises the substeps of:

fd.) calculating with said computer corrections for the adjustable filtering parameters of said IIR filter and said FIR filter;

fe.) making said corrections to the adjustable filtering parameters of said IIR filter and said FIR filter; and

ff) applying to said IIR filter and said FIR filter the resulting corrected adjustable filtering parameters, whereupon the step (f.) has been performed so that the adjustable filtering parameters for said IIR filter and said FIR filter satisfactorily reduce all ghosts in the updated separated GCR signal.

19. A method as set forth in any of Claims 7 to 18, wherein each of the steps (c.) and (i.) comprises the substeps of:

using said computer to calculate th DFT of said separat d GCR signal loaded int said computer in the just previous step; and

th n using said computer to divid the terms of th DFT of said separated GCR signal by the corresponding terms of the DFT of said ghost-free GCR signal stored in said p rmanent memory and read therefrom, thereby to generate

the DFT of said reception channel, the terms of the DFT of said reception channel comprising the set of channel characterization results g n rat d by the step.

20. A method of operating apparatus comprising a receiver for receiving through a reception channel a video signal with accompanying ghost-cancelling reference (GCR) signal both subject at times to being ghosted;

an IIR filter of a type having adjustable filtering parameters that can be adjusted for suppressing in its output response trailing macroghosts or post-ghosts accompanying its input signal;

a first FIR filter of a type having adjustable filtering parameters that can be adjusted for suppressing in its output response leading macroghosts or preghosts accompanying its input signal;

a second FIR filter of a type having adjustable filtering parameters that can be adjusted for suppressing in its output response microghosts accompanying its input signal;

a ghost- suppression filter connected for responding to said video signal which ghost-suppression filter comprises the cascade connection of said IIR filter, said first FIR filter, and said second FIR filter;

a computer for calculating the adjustable filtering parameters of said first and said second digital filters, said computer being provided with a read-only memory for permanently storing data descriptive of ghost-free GCR signal and with further memory for purposes of temporary storage; and

a GCR-signal separator for separating from the response of said ghost-suppression filter to said video signal the response of said ghost-suppression filter to said received GCR signal, subject at times to being ghosted, to supply a separated GCR signal: said method comprising the steps of:

a.) initializing the adjustable filtering parameters of said first and second digital filters;

b.) loading said separated GCR signal into said further memory of said computer, for purposes of temporary storage, which loading is done after step (a.) and can be done after other steps in the method as prescribed hereafter in this claim or any claim depending therefrom;

c.) each time after step (b.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal loaded into said computer during that step (b.) to generate a set of updated channel charact riza-

tion results;

d.) each time after step (c.) is perform d, temporarily st ring within th furth r memory of said computer the set of updated channel characterization results generated by that step (c.);

e.) each time after step (c.) is performed, determining within said computer whether or not ghosting conditions have changed, by comparing each portion of the updated set of channel characterization results with the corresponding portion of the previously temp r-arily stored set of channel characterization results, ghosting conditions being determined not to have changed only when corresponding portions of the compared sets of channel characterization results in every comparison differ by less than a first threshold value, th method looping back to step (b.) when ghosting conditions are determined to have changed when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or more than said first threshold value;

f.) each time ghosting conditions are determined not to have changed when step (e.) is performed, thereafter performing calculations within said computer for determining the adjustable filtering parameters for said IIR filter, said first FIR filter and said second FIR filter in the cascade connection which said ghost- suppression filter comprises;

g.) after step (f.) has been performed so that the adjustable filtering parameters for said IIR filter, said first FIR filter and said second FIR filter satisfactorily reduce all ghosts in the updated separated GCR signal, proceeding from step (f.) to step (h.);

h.) loading an updated separated GCR signal into said further memory of said computer, for purposes of temporary storage:

i.) each time after step (h.) is performed, performing calculations within said computer for characterizing the reception channel as described by the separated GCR signal load d into said computer during that step (h.) to generate a set of updated channel characterization results;

j.) each time after step (i.) is performed, temporarily storing within the further memory of said computer the s t of updated channel characterization results generated by that step (i.); and

k.) each time after step (i.) is performed, determining within said c mputer whether or not ghosting conditions hav chang d, by comparing each portion of the updated s t of

channel characterization results with the corresponding portion of the previously temporarily stored set of channel characterizati n results, ghosting conditions being determined not to have changed only when corresponding portions of the compared sets of channel characterization results in every comparison differ by less than a second threshold value, the method looping back to step (a.) when ghosting conditions are determined to have changed when corresponding portions of the compared sets of channel characterization results in any of said comparisons differ by as much as or more than said second threshold value.

21. A method as set forth in Claim 20, wherein said step (f.) comprises the substeps of:

    fa.) calculating with said computer adjustable filtering parameters for said IIR filter on a separable basis and applying them to said [IR filter;

    fb.) calculating with said computer adjustable filtering parameters for said first FIR filter on a separable basis and applying them to said first FIR filter;

    fc.) calculating with said computer adjustable filtering parameters for said second FIR filter on a separable basis and applying them to said second FIR filter;

    fd.) determining whether or not the adjustable filtering parameters of said IIR filter, said first FIR filter and said second FIR filter required adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value;

    fe.) counting the determinations that the adjustable filtering parameters of said IIR filter, said first FIR filter and said second FIR filter required adjustment in the current step (f.) in order to reduce all ghosts below a prescribed first threshold value, the count being initially zero and being reset to zero whenever there is a determination that the adjustable filtering parameters of said IIR filter and said FIR filter do not require adjustment in the current step (f.) in order to reduce all ghosts below said first threshold value;

    fg.) looping back to step (b.) responsive to said count being below a prescribed count and the det rmination that the adjustable filtering parameters of said IIR filter and said FIR filter require adjustment in the current step (f.) in order to reduce all ghosts below said threshold value.

22. A method as set forth in Claim 21, wherein in said step (f.) said substep (fa.) is performed before

said substep (fb.).

23. A method as set forth in Claim 21, wherein in said step (f.) said substep (fa.) is performed after said substep (fb.).

24. A method as set forth in Claim 21, 22 or 23, wherein said substep fc.) comprises the sub-sub-steps of:

    reading from said further memory of said computer, the DFT of said separated GCR signal most recently computed and temporarily stored; calculating with said computer a first truncated DFT, which is of the convolution of the response of said second filter with said separated GCR signal most recently computed and temporarily stored;

    reading from said permanent memory of said computer, terms of a second truncated DFT, which is of the ghost-free GCR signal as convolved by a desired reception channel response;

    determining with said computer the departures of the terms of said first truncated DFT from the corresponding terms of the second truncated DFT; and

    responding to each said departure for updating the corresponding adjustable filtering parameter for said second filter with its previous value as incremented or decremented by an adjustment which is in a direction to reduce that departure and which has an amplitude that is a prescribed fraction of that departure.

25. An apparatus as recited in any of the preceding claims, adapted to perform a method as set forth therein.

26. An apparatus according to claim 25, comprising a televison and/or video recorder and/or player.

Fig. 1

TV RECEIVER FRONT END `20`

antenna `30`

SOUND

SYNC

COMPOSITE VIDEO WITH GHOSTS

ADAPTIVE GHOST-SUPPRESSION CIRCUITRY `40`

GCR SIGNAL SEPARATOR `45`

DEGHOSTED COMPOSITE VIDEO

TELEVISION MONITOR OR VIDEO TAPE MACHINE `10`

FROM OSC 70

DIGITAL COMPOSITE VIDEO SIGNAL FROM `50`

ZERO-XING DETECTOR `71`

ACCUMULATOR `36`

DECODE LINE 19(& 18) `58`

`310`

MUX

PIXEL COUNTER `72`

DECODE CHIRP REGION `364`

DECODE END OF LINE `42`

`365`

`31`

TEMPORARY (2) LINE STORE RAM

WRITTEN IN PIXEL LATCH `32`

Σ `34`

READ OUT PIXEL LATCH `33`

ADDER

`362` ZERO

MUX

`363`

LATCH

`361`

RESET TO 001 `39`

MODULO-8 (x 2) FIELD COUNTER

ABSOLUTE VALUE `35`

`57`

DECODE LAST TWO BITS NOT 01 `41`

THRESHOLD DETECTOR `38` `37`

Fig. 3

Fig. 2

81 — START
STEP

82 — RESET ALL DEGHOST FILTERS

83 — ACQUIRE DATA

84 — CHANNEL CHARACTERIZATION

N ◁— STABLE GHOSTS (*) ? —— 85

Y

STEPS
86 & 87
CAN BE IN
OPPOSITE
ORDER

UPDATE IIR COEFFICIENTS —— 86

UPDATE FIR COEFFICIENTS —— 87

88 — GHOST BELOW THRESHOLD ? —N→ MAX NO. OF ITERATIONS ? —— 89

N

Y   Y

90 — UPDATE EQUALIZATION COEFFICIENTS

91 — ACQUIRE DATA
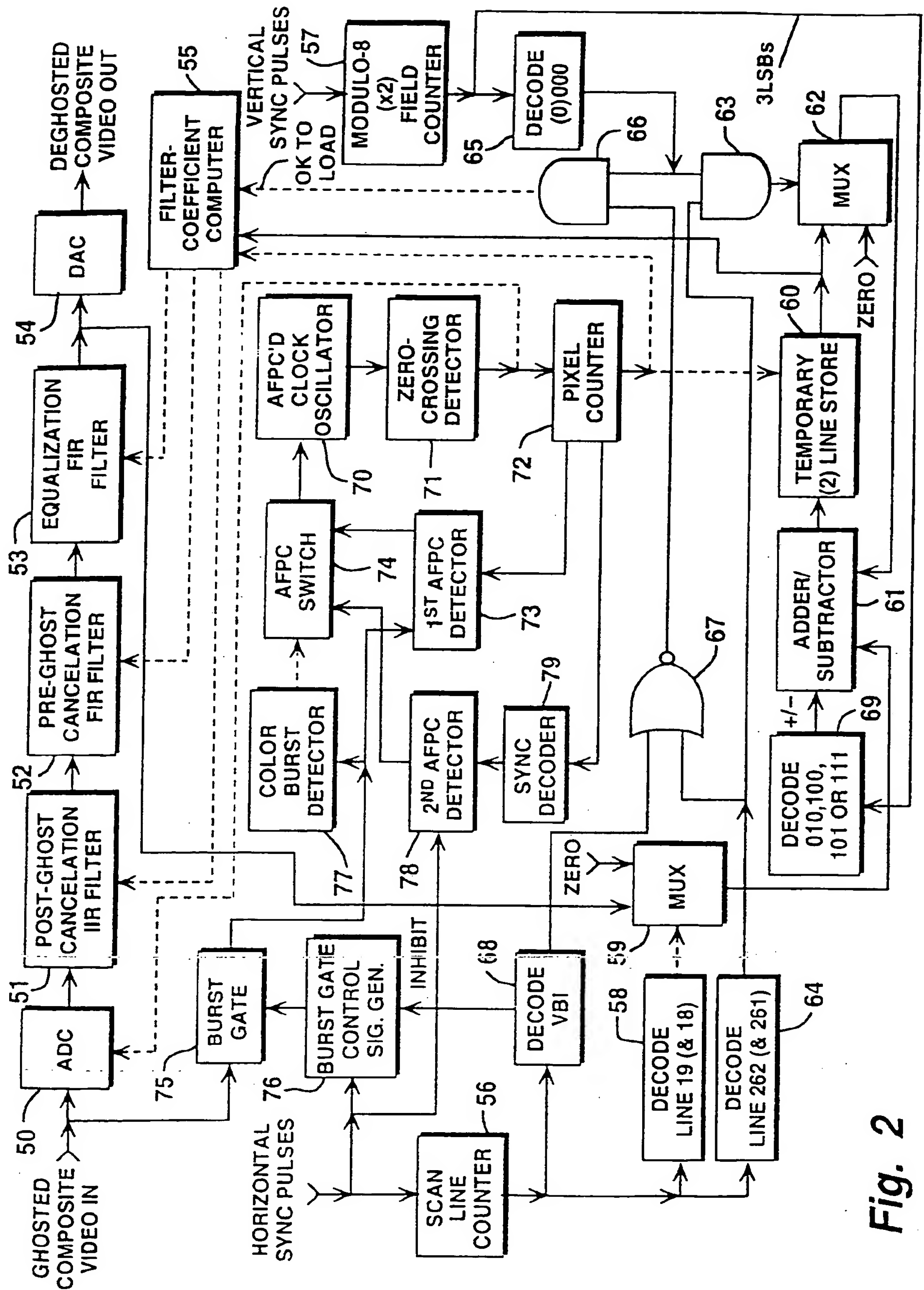
CHANNEL CHARACTERIZATION

92

93 — GHOSTS SAME (**) ? —N→
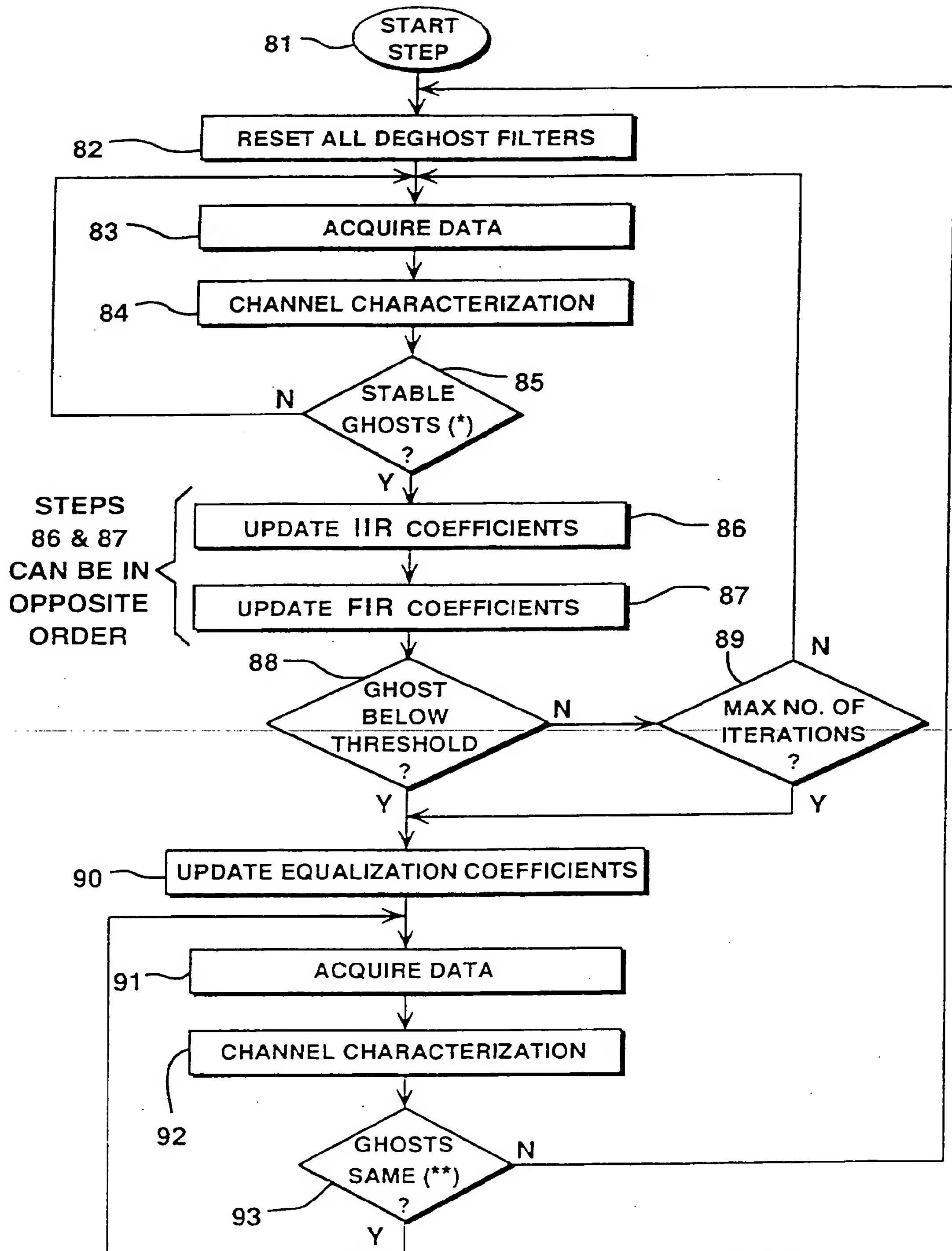
Y

(*) DIFFERENCE BETWEEN TWO CONSECUTIVE CHANNEL ESTIMATIONS
IS BELOW THRESHOLD

(**) RESIDUE GHOSTS IN BOTH STEP 84 AND STEP 92 CHANNEL
CHARACTERIZATIONS ARE ALL BELOW THRESHOLD

Fig. 4

START
STEP

81

82 — RESET ALL DEGHOST FILTERS

83 — ACQUIRE DATA

84 — CHANNEL CHARACTERIZATION

N — STABLE GHOSTS (*) ? — 85

Y

STEPS
86 & 87
CAN BE IN
OPPOSITE
ORDER

UPDATE IIR COEFFICIENTS — 86

UPDATE FIR COEFFICIENTS — 87

94 — UPDATE EQUALIZATION COEFFICIENTS

88 — GHOST BELOW THRESHOLD ? — N — 89 — MAX NO. OF ITERATIONS ? — N

Y — Y

91 — ACQUIRE DATA
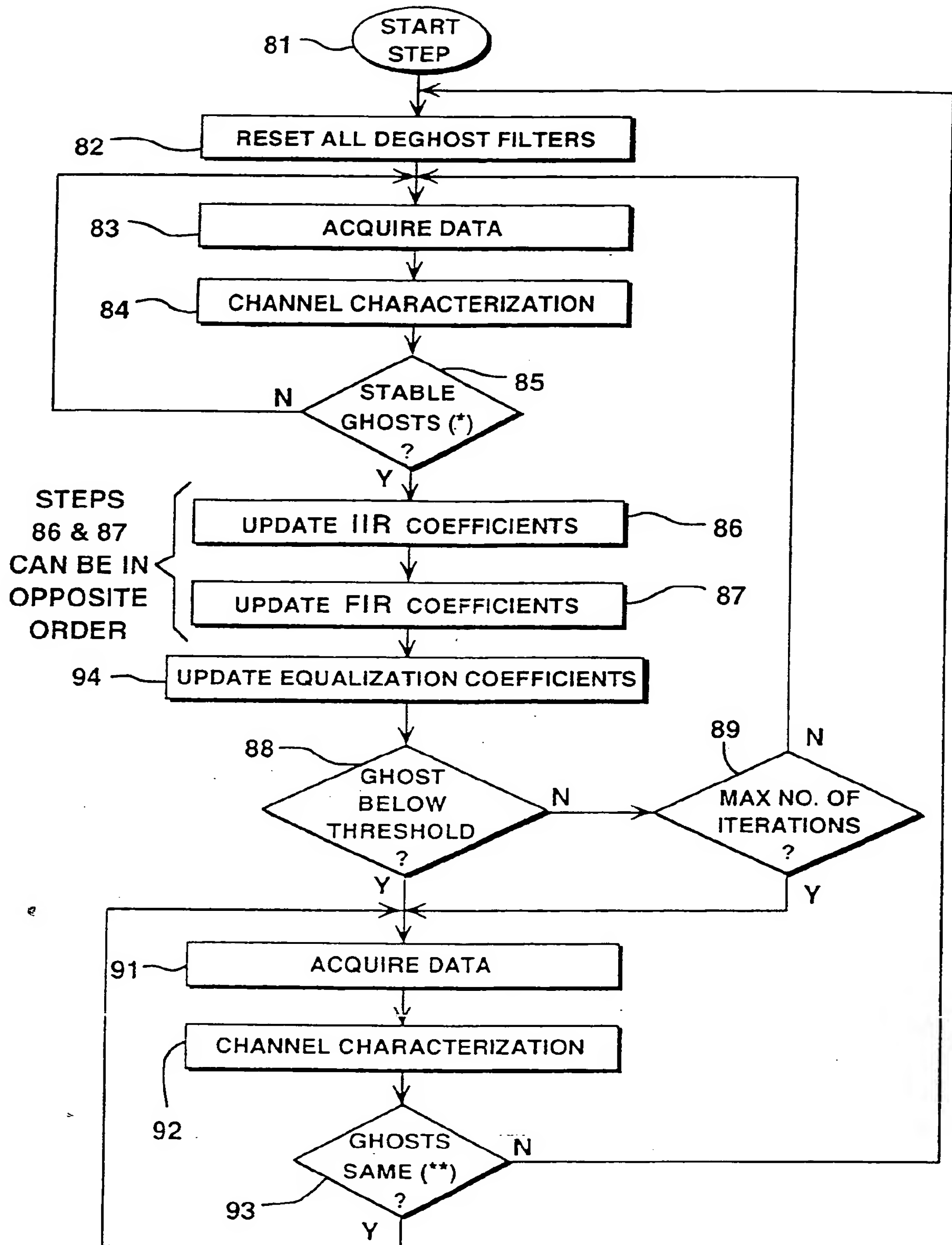
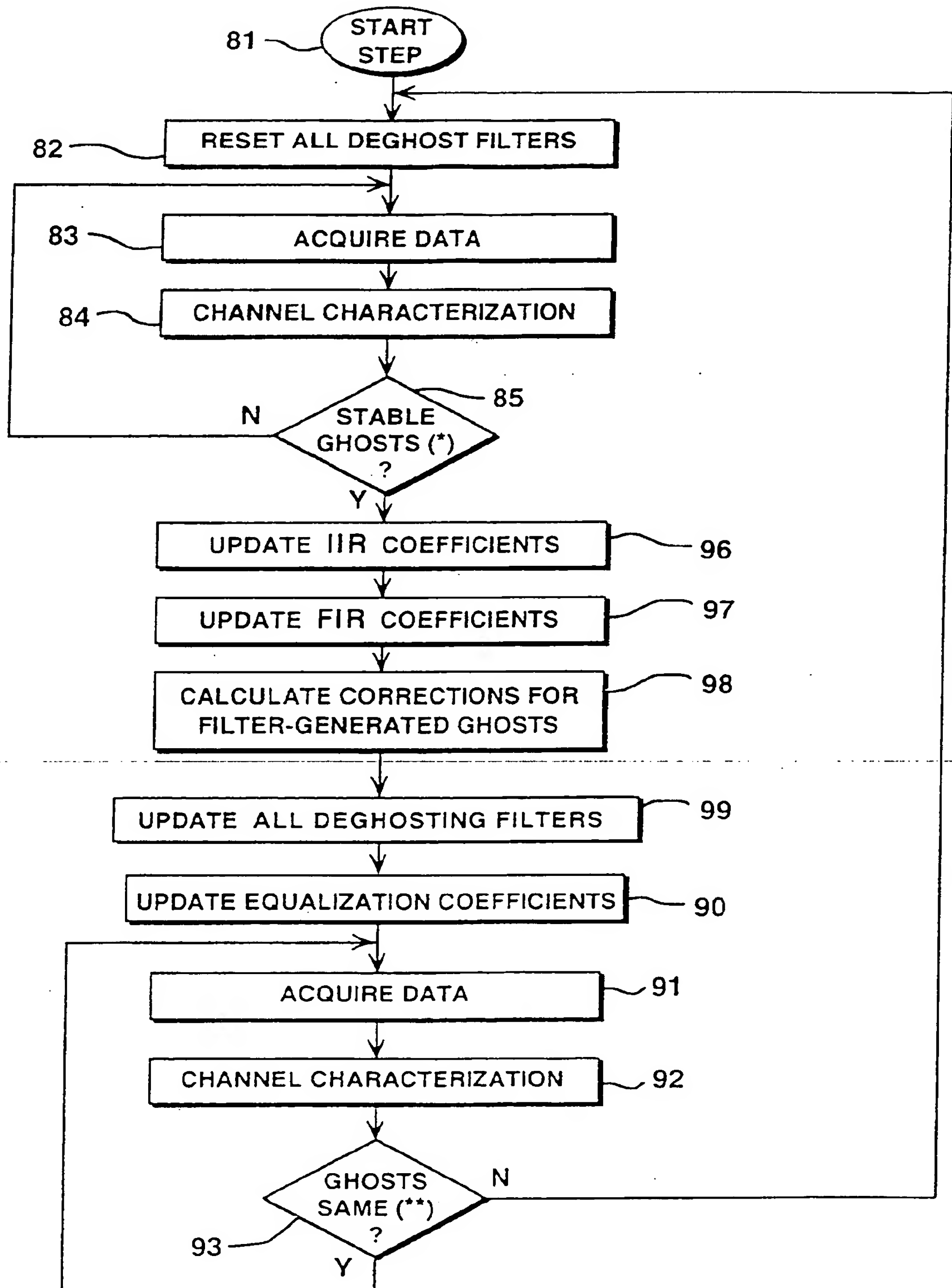CHANNEL CHARACTERIZATION

92 — GHOSTS SAME (**) ? — N

93 — Y

(*) DIFFERENCE BETWEEN TWO CONSECUTIVE CHANNEL ESTIMATIONS
IS BELOW THRESHOLD

(**) RESIDUE GHOSTS IN BOTH STEP 84 AND STEP 92 CHANNEL
CHARACTERIZATIONS ARE ALL BELOW THRESHOLD

Fig. 5

81 — START STEP

82 — RESET ALL DEGHOST FILTERS

83 — ACQUIRE DATA

84 — CHANNEL CHARACTERIZATION

N — STABLE GHOSTS (*) ? — 85

Y

UPDATE IIR COEFFICIENTS — 96

UPDATE FIR COEFFICIENTS — 97

CALCULATE CORRECTIONS FOR FILTER-GENERATED GHOSTS — 98

UPDATE ALL DEGHOSTING FILTERS — 99

UPDATE EQUALIZATION COEFFICIENTS — 90

ACQUIRE DATA — 91

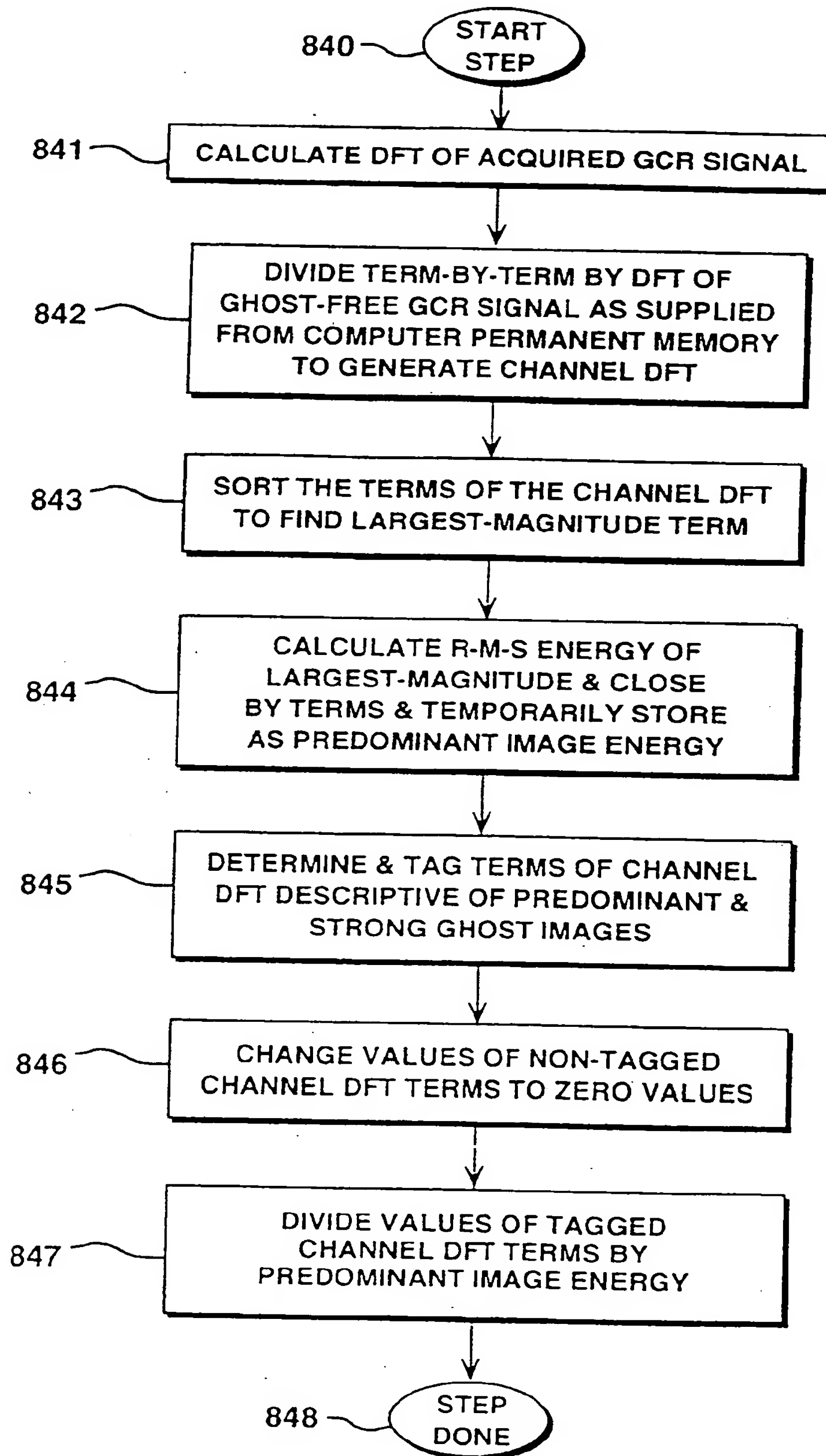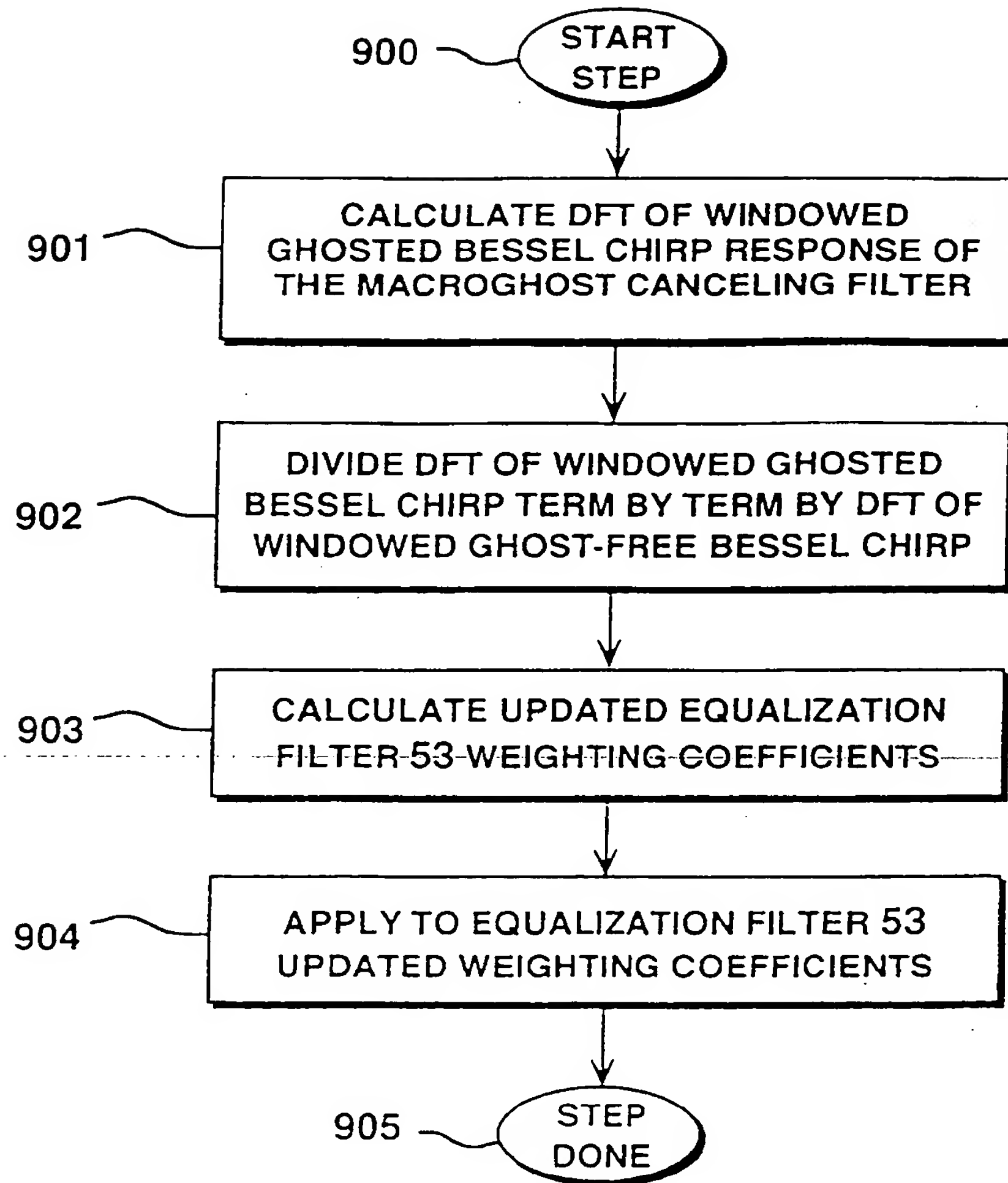CHANNEL CHARACTERIZATION — 92

GHOSTS SAME (**) ? — N

93 — Y

(*) DIFFERENCE BETWEEN TWO CONSECUTIVE CHANNEL ESTIMATIONS IS BELOW THRESHOLD

(**) RESIDUE GHOSTS IN BOTH STEP 84 AND STEP 92 CHANNEL CHARACTERIZATIONS ARE ALL BELOW THRESHOLD

Fig. 6

840 — START STEP

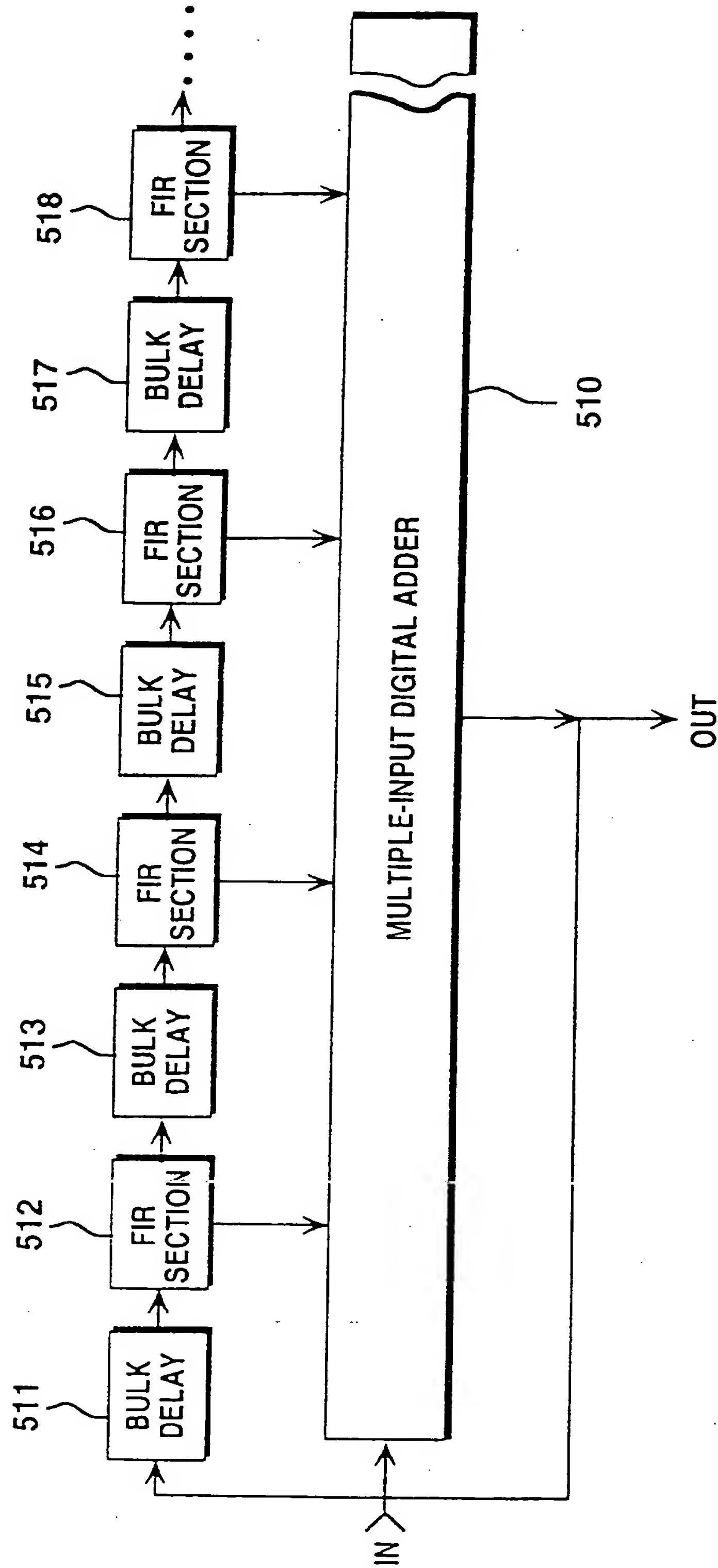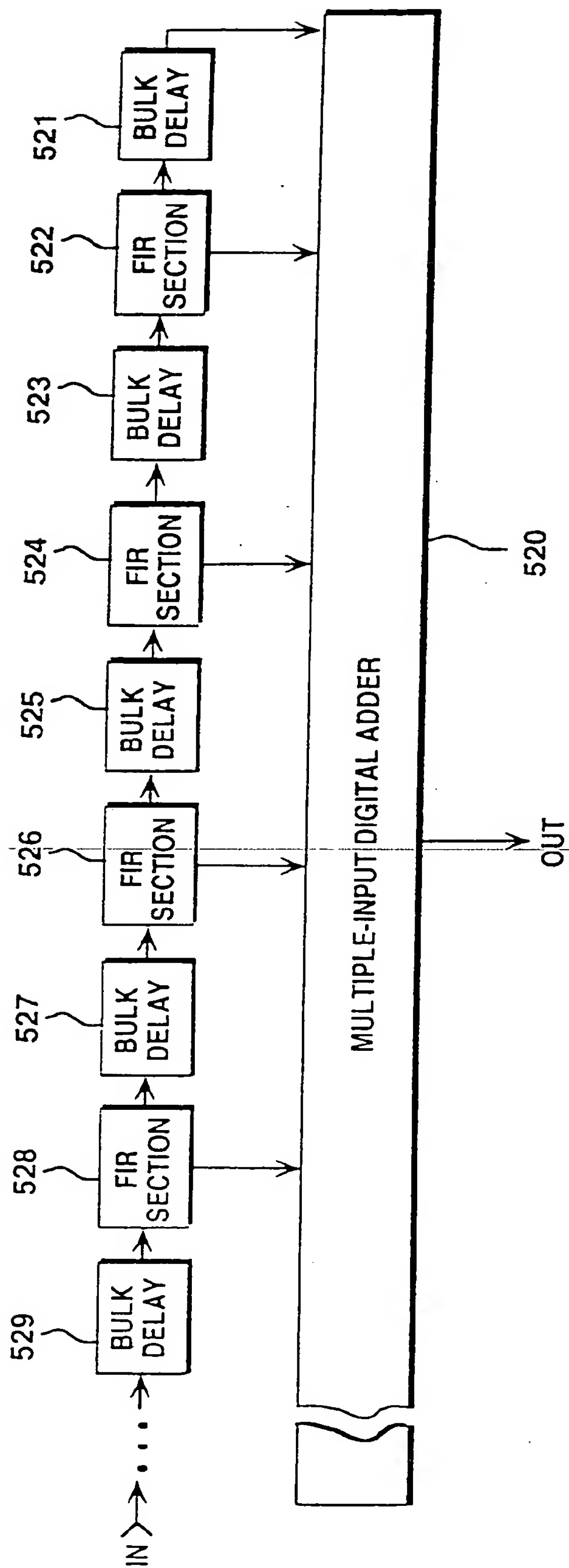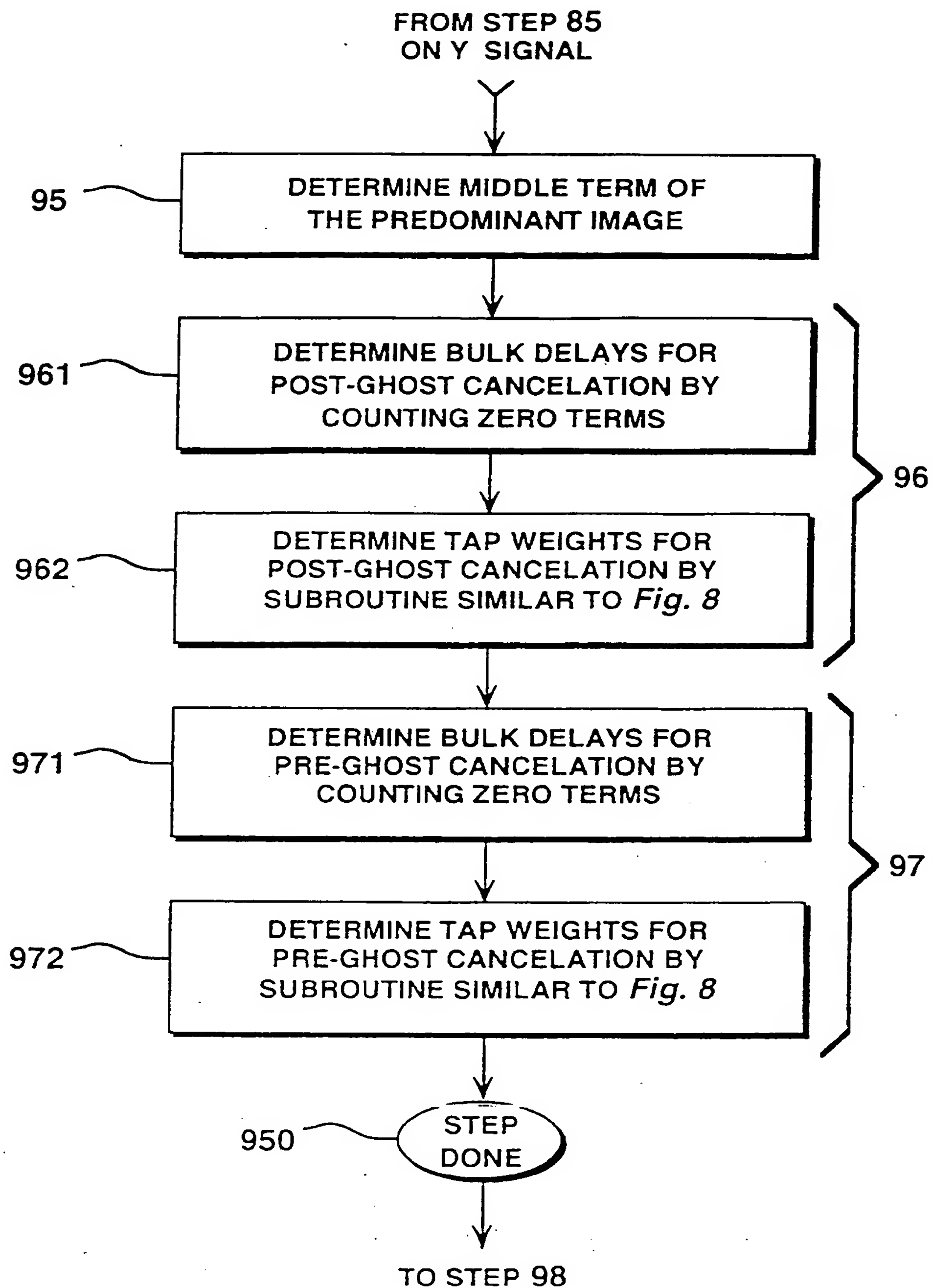841 — CALCULATE DFT OF ACQUIRED GCR SIGNAL

842 — DIVIDE TERM-BY-TERM BY DFT OF GHOST-FREE GCR SIGNAL AS SUPPLIED FROM COMPUTER PERMANENT MEMORY TO GENERATE CHANNEL DFT

843 — SORT THE TERMS OF THE CHANNEL DFT TO FIND LARGEST-MAGNITUDE TERM

844 — CALCULATE R-M-S ENERGY OF LARGEST-MAGNITUDE & CLOSE BY TERMS & TEMPORARILY STORE AS PREDOMINANT IMAGE ENERGY

845 — DETERMINE & TAG TERMS OF CHANNEL DFT DESCRIPTIVE OF PREDOMINANT & STRONG GHOST IMAGES

846 — CHANGE VALUES OF NON-TAGGED CHANNEL DFT TERMS TO ZERO VALUES

847 — DIVIDE VALUES OF TAGGED CHANNEL DFT TERMS BY PREDOMINANT IMAGE ENERGY

848 — STEP DONE

Fig. 7

900 — START
STEP

901 — CALCULATE DFT OF WINDOWED
GHOSTED BESSEL CHIRP RESPONSE OF
THE MACROGHOST CANCELING FILTER

902 — DIVIDE DFT OF WINDOWED GHOSTED
BESSEL CHIRP TERM BY TERM BY DFT OF
WINDOWED GHOST-FREE BESSEL CHIRP

903 — CALCULATE UPDATED EQUALIZATION
FILTER 53 WEIGHTING COEFFICIENTS

904 — APPLY TO EQUALIZATION FILTER 53
UPDATED WEIGHTING COEFFICIENTS

905 — STEP
DONE

Fig. 8

Fig. 9

Fig. 10

FROM STEP 85
ON Y SIGNAL

95 — DETERMINE MIDDLE TERM OF
THE PREDOMINANT IMAGE

961 — DETERMINE BULK DELAYS FOR
POST-GHOST CANCELATION BY
COUNTING ZERO TERMS

96

962 — DETERMINE TAP WEIGHTS FOR
POST-GHOST CANCELATION BY
SUBROUTINE SIMILAR TO *Fig. 8*

971 — DETERMINE BULK DELAYS FOR
PRE-GHOST CANCELATION BY
COUNTING ZERO TERMS

97

972 — DETERMINE TAP WEIGHTS FOR
PRE-GHOST CANCELATION BY
SUBROUTINE SIMILAR TO *Fig. 8*

950 — STEP
DONE

TO STEP 98

Fig. 11

940 — START STEP

941 — CALCULATE DFT OF WINDOWED GHOSTED BESSEL CHIRP RESPONSE FOR THE MACROGHOST CANCELING FILTER

942 — CROSS-CORRELATE DFT OF WINDOWED GHOSTED BESSEL CHIRP RESPONSE WITH DFT OF WINDOWED GHOST-FREE BESSEL CHIRP

943 — CALCULATE CHANGES IN "MIDDLE" CROSS-CORRELATION TERMS TO FIT DESIRED CORRELATION RESPONSE

944 — INCREMENT WEIGHTS OF CORRESPONDING TAPS OF EQUALIZATION FILTER BY FRACTION OF CHANGES

945 — STEP DONE

Fig. 12

980 — START STEP

981 — ARE THERE BOTH PRE- & POST-GHOSTS ? — N

Y

982 — CALCULATE DFT OF CONVOLVED IIR & FIR GHOST-CANCELATION FILTER RESPONSES

983 — DETERMINE STRONG "FILTER-GENERATED" GHOSTS LOCATIONS & RECHARACTERIZE CHANNEL

984 — REDETERMINE BULK DELAYS FOR POST-GHOST CANCELATION BY COUNTING ZERO TERMS

985 — REDETERMINE TAP WEIGHTS FOR POST-GHOST CANCELATION BY SUBROUTINE SIMILAR TO *Fig. 8*

986 — REDETERMINE BULK DELAYS FOR PRE-GHOST CANCELATION BY COUNTING ZERO TERMS

987 — REDETERMINE TAP WEIGHTS FOR PRE-GHOST CANCELATION BY SUBROUTINE SIMILAR TO *Fig. 8*

988 — STEP DONE

99 — UPDATE ALL DEGHOSTING FILTERS

Fig. 13

(54) Video ghost cancellation.

(57)   Ghosts accompanying a composite video signal are suppressed using one filter to suppress macroghosts and another filter to suppress microghosts, the filtering parameters of each of these filters being adjustable in response to digital programming signals generated by a computer. Computational methods are described, each of which includes data acquisition and channel characterization steps followed by a decision step comparing the most recent set of channel characterization results with the next most recent set to determine whether stable ghosting conditions obtain. The data acquisition and channel characterization steps are looped back through until stable ghosting conditions obtain, so the subsequent calculations of the filtering parameters for the filter used for suppressing macroghosts are accurately performed. Where the filter to suppress macroghosts comprises IIR and FIR sections for suppressing post-ghosts and preghosts, respectively, these calculations are carried out to a great extent on a separable basis, simplifying the calculations appreciably. Then, each of these methods performs a step of calculating the filtering parameters for the FIR filter used for suppressing microghosts. This step is followed by further data acquisition and channel characterization steps, followed by a decision step comparing the most recent set of further channel characterization results with the next most recent set of further channel characterization results to determin wheth r they are substantially th sam . If th sets of further channel characterization results are substantially the same, ither m thod loops back to the

further data acquisition step ; if the sets differ appreciably, either method resets the adjustable filtering parameters for the filters to initial values and the method restarts automatically.

Fig. 4

(*) DIFFERENCE BETWEEN TWO CONSECUTIVE CHANNEL ESTIMATIONS IS BELOW THRESHOLD

(**) RESIDUE GHOSTS IN BOTH STEP 34 AND STEP 92 CHANNEL CHARACTERIZATIONS ARE ALL BELOW THRESHOLD

EP 0 600 739 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 93 30 9678

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
P,A	EP-A-0 516 216 (N. V. PHILIPS' GLOEILAMPENFABRIEKEN) * page 1, line 11 - line 53 * * page 3, line 36 - page 4, line 46; figures 1-4 * ---	1,2,7, 20,25	H04N5/21
A	EP-A-0 450 720 (N. V. PHILIPS' GLOEILAMPENFABRIEKEN) * page 2, line 10 - page 3, line 7; figure 6 * -----	1,2,7, 20,25	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

H04N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	8 May 1995	Dudley, C

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